March 2, 2007

Hand Delivered

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New Castle, DE 19720

DuPont Comments to Schnabel Engineering Report entitled
Hay Road Sludge Drying Site, Cherry Island, Wilmington, Delaware
dated December 20, 2006

Dear Dr. Salahuddin:

Enclosed are DuPont comments on the Schnabel Engineering's independent, third-party report (Schnabel Report). DuPont appreciates the work that went into developing the independent study and we have worked hard to provide substantive comments on the report. We believe that completion of the independent review fully satisfies the requirements of House Concurrent Resolution No. 22.

Although the Schnabel Report does not recommend a change in proposed remedy, it does recommend certain additional actions be taken before a remedial decision is made. Based on our review, DuPont has developed detailed comments on the Schnabel Report's findings and recommendations that may be generalized in two ways.

First, there are certain findings or recommendations in the report with which we technically disagree. An example of a comment such as this might be a technical disagreement over whether additional data are necessary (or not) to support a remedial decision or the number of samples needed to make a remedial decision. Second, there are certain findings or recommendations that DuPont believes are inaccurate or incorrect. An example of a comment such as this might be where there is a mathematical error in a calculation used to support a finding or recommendation by Schabel.

We have organized our comments in the following manner. First, we present an overview of our comments as Attachment 1 of this letter. Second, Attachment 2 is a point-by-point response to specific comments within the Schnabel Report.

DuPont remains confident that the in-place remedy (capping) presents the lowest risk and is the most timely and cost-effective alternative for remediating the Iron-Rich site. This alternative is supported by the data submitted to the Delaware Department of Natural Resources and Environmental Control (DNREC) following many years of investigations and studies as well as information presented during multiple public forums.

Thank you for the opportunity to comment on the independent, third-party study. DuPont stands ready to meet with DNREC should the agency require additional information or need clarification of the information submitted in this cover letter or any of the accompanying attachments.

Sincerely,

Thomas S. Andersen
Environmental Manager
DuPont Edge Moor

Attachments (5)

1-Summary of Major DuPont Comments on Schnabel Engineering Report
2-Detailed DuPont Comments on Schnabel Engineering Report
3-List of Exhibits
4-List of Acronyms
5-Reference List

ATTACHMENT 1

SUMMARY OF MAJOR DUPONT COMMENTS ON SCHNABEL ENGINEERING REPORT

Presented below are five major areas in which the Schnabel Report presents technically inaccurate statements regarding important issues or misinterprets findings and data from existing reports cited in the study. The five major areas are as follows:

1. Proposed Capping System Operational Life – The Schnabel Report states that the operational life of high-density polyethylene (HDPE) liners is on the order of decades, citing a technical paper by Peggs (2003) as the basis for their comment. This statement is a misunderstanding of the actual contents of the paper referenced. The paper by Peggs states "…our practical experience with HDPE geomembranes is limited to about 25 years." In fact, the Peggs paper concludes that if high-quality geomembrane materials are used, in conjunction with good design and quality construction practices then a "HDPE geomembrane in a MSW [municipal solid waste] landfill should last for about 400 years." The Peggs paper is included as Exhibit D of Attachment 2.

2. Potential Presence of DNAPLs within the Iron-Rich Pile – The Schnabel Report incorrectly concluded that hexachlorobenzene (HCB) exists as a dense, nonaqueous phase liquid (DNAPL) in the Iron-Rich Pile in relatively large volumes that could migrate to the environment. This conclusion was based on measured HCB concentrations in Iron-Rich and a partitioning calculation. Using the same basic assumptions, the estimates presented by Schnabel have been found to be overestimated by a factor of 1,000, apparently due to a unit conversion error. Simply put, HCB will not occur as a DNAPL. Rather, based on known HCB physical properties, HCB is strongly adsorbed to the Iron-Rich (a carbonaceous material). This fact is confirmed by Iron-Rich toxicity characteristic leaching procedure (TCLP) analytical data.

3. Preparation of a Focused Feasibility Study – The Schnabel Report states that DuPont did not have prior approval by the Delaware Department of Natural Resources and Environmental Control (DNREC) to prepare a focused feasibility study (FFS). The report further states that the FFS approach resulted in "two extreme choices" (cap-in-place, source removal) for remedial technology alternatives. DuPont received approval from DNREC to complete a FFS through issuance of the scope of work contained in the Voluntary Cleanup Program Agreement (dated September 11, 2002) for the Hay Road site. This approval and DNREC Hazardous Substances Cleanup Act (HSCA) guidance (1994) allowed for the FFS to use a presumptive remedy approach in the assessment of remedial technology alternatives. In fact, the Schnabel Report correctly states "A focused feasibility study considering a limited number of remedial alternatives or the use of a presumptive remedy may be used in lieu of a normal feasibility study." The two technologies evaluated by the FFS (cap-in-place, source removal) are not "extreme choices." The proposed remedy has been routinely implemented at sites throughout the country, including Delaware.

4. Adequacy of the Risk Assessments – The Schnabel Report states that the ecological and human health risk assessments have significant shortcomings with regard to evaluating wind-blown dust and wildlife access pathways for exposure. DuPont disagrees. As noted in the Schnabel Report, "The exposure pathways that were considered in DuPont's RI/RA [remedial investigation/risk assessment] report

include: direct contact, air/wind dispersion, ground water, and surface water…The risk assessment was conducted consistent with DNREC's Remediation Standard Guidance Document Under the Delaware Hazardous Substance Cleanup Act, dated December 1999 (DRNEC, 1999)."

In addition to DNREC's requirements, DuPont performed extensive evaluations of the potential for exposure to wind-blown dust to receptors in adjacent water bodies. These evaluations concluded that there was *de minimus* risk from these past releases.

Further, the Schnabel Report also concludes that the Iron-Rich material storage area is not a "robust wildlife habitat," and that "the completion of the proposed remedy will reduce/eliminate the direct contact route." DuPont agrees and believes that neither of these exposure pathways will be a concern once the site is remediated.

5. Personal Protective Equipment (PPE) – In the conclusions and recommendations sections of the report, Schnabel implies that an inappropriate level of PPE and monitoring was being employed by workers at the site during a visit in July 2006. DuPont implemented a comprehensive perimeter air monitoring program during the regrading of the Iron-Rich pile in 2002. This program included a PPE level that protected workers from potential airborne particulates, skin contact, and potential inadvertent ingestion of solids from the pile. Data generated from this project established appropriate PPE levels for future site activities based on the type of work undertaken on-site. DuPont has and will continue to implement appropriate PPE measures to ensure that on-site workers are working in a safe environment. In addition, on the day Schnabel visited the site, there were no workers present other than the DuPont employees who accommodated Schnabel's tour. Visitors were some distance from the Iron-Rich material at all times on that day.

ATTACHMENT 2

DETAILED DUPONT COMMENTS ON SCHNABEL ENGINEERING REPORT

Schnabel Statement—Section 2.2.2, Geology and Soils

…Permeability data is provided for several sampling locations west of the IRM storage pile. However, samples of the material beneath the IRM storage pile were not collected, and therefore not evaluated for their permeability characteristics.

DuPont Comment #1

Extensive geotechnical investigations have been conducted at the site, including multiple studies in the early 1970s, Cell 2 investigations (1977), Cell 3 investigations (1978 through 1979), Cell 4 investigation (1990), landfill closure investigation (1992), and the pre-design investigation (2000). Exhibit A illustrates the numerous soil borings, test pits, wells, and piezometers that have been employed to understand the site subsurface. DuPont is aware that heterogeneities may influence the bulk permeability of a unit. However, sand beds or laminations within the dredged materials were thin and not laterally correlative, indicating they are likely discontinuous lenses rather than extensive flow pathways.

As Schnabel states, permeability data are available for several locations west of the IRM storage pile at various depths. Boring logs are also available for locations across the site, both in the areas where the permeability data were collected and under the IRM pile (see Exhibit A). The logs of the 14 borings within or on the margin of the footprint of the IRM pile indicate that the materials beneath the pile are comparable to those used for the permeability analyses. The hydraulic conductivity value of 4.6×10^{-2} cm/sec cited by Schnabel was obtained from the Shallow Sand unit in the western portion of the site, not from the DM that underlies the IRM storage area. The highest vertical hydraulic conductivity measured on any of the DM at the site was 1.1×10^{-5} cm/sec.

Schnabel Statement—Section 2.2.2, Geology and Soils

…The seasonal variations in the rate and volume of ground water, surface water interactions, recharge and discharge areas are not discussed in sufficient detail.

DuPont Comment #2

The seasonal variations in the hydrogeological flow system at the site are typical of any groundwater flow system in northern New Castle County, Delaware. The water table is expected to be relatively higher during wet periods of the year and lower during dry periods of the year. The IRM was placed above the seasonal high water table. Per the in-place closure remedy scenario (i.e., capping), the IRM would continue to remain above the water table. This placement dramatically limits the potential for COPCs in the IRM to leach into the groundwater.

Over the past 20 years, the solid waste landfill permit has required water level measurements to be obtained from selected wells at different times of the year. These water level data clearly show the groundwater surface water interactions and provided DuPont with sufficient information to address seasonal variations as they pertain to the remedial alternatives.

Schnabel Statement—Section 2.2.2, Geology and Soils

It is our opinion that sufficient data was presented regarding the chemical characteristic of the DM in specific areas of the site, but we believe that this data may not reflect the IRM's impact on the dredged material in the eastern portion of the site…

DuPont Comment #3

DuPont agrees that sufficient data were presented to chemically characterize DM in specific areas of the site (samples DM-1 through DM-14). DuPont believes that the results from these samples would be consistent with results from samples collected on the eastern portion of the site.

Schnabel Statement—Section 2.2.3, Hydrology and Saturation Zones

Sufficient information and data were provided detailing both surrounding bodies of water including flow, stream dimensions, and water quality. Insufficient information was provided on flooding tendencies and surface to ground water relationships.

DuPont Comment #4

DuPont agrees with Schnabel's comment that sufficient information and data were provided detailing both surrounding bodies of water, including flow, stream dimensions, and water quality. DuPont obtained USGS peak stream flow data from 1945 to 2006 on the flooding tendencies of the river (see Exhibit B). These data show that the highest recorded stream flow of Shellpot Creek occurred in 1989 at elevation 13.76 feet MSL (NGVD29) or elevation 12.63 feet MSL (NAVD88). It is important to note that USGS stream flow data in Exhibit B are presented in NGVD29, not NAVD88. For comparison purposes, the topographic low point of the berm is at elevation 17.13 feet MSL NGVD29 or 16.0 feet MSL NAVD88. This comparison shows that the highest historical flood on record (12.63 feet MSL NAVD88) remains lower than the lowest point of the berm. Furthermore, this low point berm elevation (elevation 16.0 MSL NAVD88) is well above the 100- and 500-year floodplain elevations of 8.87 and 10.0 feet MSL NAVD88, respectively.

Schnabel Statement—Section 2.2.4, Meteorology and Climate

Neither temperature data nor discussions on extreme weather conditions were present. The temperature may have little relevance to the IRM; however, extreme weather conditions, including hurricanes and associated flooding which pose possible threats were not discussed.

DuPont Comment #5

DuPont acknowledges that extreme weather conditions, such as hurricanes with their high wind velocities, could have a detrimental impact on the current IRM pile. However, DuPont believes that these extreme weather conditions affect elevated structures and would not affect the vegetative cover and soil proposed as part of the geosynthetic capping system of the cap-in-place remedy. As stated previously, the IRM pile is well above the 100- and 500-year floodplain elevations of 8.87 and 10.0 feet MSL NAVD88, respectively. In addition, review of the peak stream flow of Shellpot Creek (see Exhibit B) revealed a peak elevation of 13.76 feet MSL (NDVD29) or 12.13 feet MSL (NAVD88). This is well below the low berm elevation of 16.0 feet MSL (NAVD88).

In the unlikely event of a storm surge higher than 16 feet MSL NAVD88 (the low point of the berm), flood water would only temporary inundate a small portion of the capping system. The flood water would be drained away by the surface drainage controls, which would be designed in accordance with DNREC regulations. This drainage would occur without damaging the HDPE capping membrane. Vegetation and cap cover soils above the membrane could be eroded away, but could quickly be replaced.

Schnabel Statement—Section 2.2.5, Proximities

…We noted that there is a topographic low in the berm separating the site from the Delaware River near the southeast corner of the site and near stormwater outfall D002. This topographic low may alter the effectiveness of the berm in relation to high stage flooding. Because of this, it is our opinion that the reliance on the FEMA Flood Insurance Map is not sufficient.

DuPont Comment #6

The topographic low outside of the berm separating the site from the Delaware River near Outfall D002 referenced above corresponds to an elevation of approximately 9.0 feet MSL NAVD88 at the base of the rip-rap at Outfall D002 (see Exhibit C). This exhibit presents the 100-year floodplain of 8.87 feet MSL NAVD88 as a thick dashed line. The elevation at the base of Outfall D002 is a localized topographic low area that quickly increases in elevation to approximately 16.6 feet MSL NAVD88 at the access road in the southeast corner of the site. This elevation (16.6 feet MSL NAVD88) is well above the 100- and 500-year floodplain elevations of 8.87 and 10.47 feet MSL, respectively (based on NAVD88). Even with this localized topographic low, the effectiveness of the berm relative to the 100- and 500-year floodplains will not be impacted.

Schnabel Statement—Section 2.2.5, Proximities

…There is a discrepancy between this document and the RI/RA report on the elevation of the 100-year flood.

DuPont Comment #7

The elevation of the 100-year flood was reported in two separate data: NGVD29 and NAVD88. NGVD29 was developed in 1929, and NAVD88 is an updated version of NGVD29 that was developed in 1988. The 100-year floodplain elevation noted in the June 15, 2005, document is 8.9 feet MSL NAVD88. The 100-year floodplain elevation presented in the RI/RA report is 10.0 feet MSL NGVD29 based on a FEMA flood insurance map dated April 17, 1996 (DuPont, 2004a). The datum used for the FEMA map (NGVD29) is different than the current datum used in Delaware for elevation determination (NAVD88) by 1.13 feet. That is, the current Delaware State Plane (NAVD88) is 1.13 feet lower than the elevations presented on the FEMA map (NGVD29). Therefore, the 10.0 feet MSL NGVD29 elevation presented on the FEMA map for the 100-year floodplain corresponds to a current elevation of 8.87 feet MSL NAVD88. DuPont will use the NAVD88 datum in all future reports.

Schnabel Statement—Section 2.4.1, Dredged Material

Information was not provided regarding the chemical characterization of the DM prior to DuPont's activities at the site. Recent samples of DM were collected for chemical analysis from within the confines of the original 22.5 acre IRM storage area footprint. It is our opinion that by limiting the sample locations to the previous IRM footprint, they did not achieve an adequate determination of the extent or presence of IRM-related contamination within the DM.

DuPont Comment #8

No information is available regarding the chemical characterization of the DM prior to DuPont activities at the site. Leachate and groundwater flow modeling has been performed by ENVIRON (2003). The leachate model used was the USEPA HELP model (USEPA, 1994). The groundwater flow model used was the Oak Ridge National Laboratories AT123D model (USEPA, 1989). The modeling results demonstrated that the COPCs do not pose any appreciable risks through leaching and transport to nearby surface water bodies.

Schnabel Statement—Section 2.4.1, Dredged Material

A sample of DM that has not been in contact with IRM should be collected and analyzed to compare and establish the extent of IRM-related contamination, if any, in the dredged material.

DuPont Comment #9

Leachate and groundwater flow modeling has been performed by ENVIRON (2003). The leachate model used was the USEPA HELP model (USEPA, 1994). The groundwater flow model used was the Oak Ridge National Laboratories AT123D model (USEPA, 1989). The modeling results demonstrated that the COPCs do not pose any appreciable risks through leaching and transport to nearby surface water bodies.

Schnabel Statement—Section 2.5.1, Direct Contact

Currently, direct contact with IRM by ecological receptors, contrary to DuPont's reports, is likely. We observed birds, rabbits and a fox on the IRM pile during our on-site visit on July 5, 2006. However, it is believed that the completion of the proposed remedy will reduce/eliminate the direct contact route, and therefore the data are sufficient.

DuPont Comment #10

Ecological receptors were addressed consistent with DNREC requirements. At the time when the RI/RA report was submitted, the IRM did not support vegetation. DuPont presumed that the remedy would be implemented in a relatively short period of time. Voluntary vegetative growth has occurred within the last year. However, DuPont agrees that the completion of the proposed remedy will eliminate the exposure route.

Schnabel Statement—Section 2.5.3, Ground Water

The ground water exposure route and supporting data are not sufficiently described in the documents as they apply to current conditions. Instead, focus is placed on the reduced leachate generating potential once a capping system is installed. With analytical data demonstrating the current leaching potential, we believe more emphasis should have been placed on the mobility and persistence of the COC. The migration path and expected exposure pathways are addressed *in subsequent paragraphs of the Final RI/RA Report. No drinking water sources are within the vicinity of the site.*

DuPont Comment #11

As Schnabel correctly noted, "No drinking water sources are within the vicinity of the site." Hence, the appropriate focus should be the potential for leaching and subsequent discharge to surface water. It should be noted that both scenarios, i.e., with and without a cap, have been evaluated. DuPont placed a significant amount of effort on evaluating this pathway for both cap and no cap scenarios. The no cap scenario could conservatively be viewed as the current condition. The Schnabel Report acknowledges this when it states "The migration path and expected exposure pathways are addressed in subsequent paragraphs of the Final RI/RA Report."

The modeling results (ENVIRON, 2003) demonstrated that under each closure option (i.e., no cap, soil protective layer and low-density polyethylene liner), leaching and migration to the nearby surface water bodies at potentially significant concentrations would not occur for at least 1,000 years—even if these constituents were present at solubility limits in the leachate. Essentially unlimited concentrations of each of the COPCs could be present in the IRM staging pile and still not result in an exceedance of risk-based surface water quality criteria.

It should be stressed that even without a cap (which can be conservatively assumed to be equivalent to current conditions) and conservatively assuming that no degradation or tidal mixing occurs, essentially unlimited concentrations of each of the COPCs may be left in place and still not result in an exceedance of risk-based surface water quality criteria.

Schnabel Statement—Section 2.6.4, Persistence and Bioaccumulative Properties

Persistence and bioaccumulative properties, including mobility and form, were not evaluated or presented in relation to contamination at or from the site. DuPont states in its RI/RA report that IRM does not support vegetation, and therefore is not a likely source of food for birds or burrowing animals. However, since the time the RI/RA report was submitted, vegetation has grown on the IRM, and therefore warrants consideration. It should be noted that this would not be an issue under either remedial alternative.

DuPont Comment #12

Consistent with standard risk assessment protocols, a site conceptual model was used to define *all relevant* COPCs, exposure pathways, and receptors. While the RI/RA process prescribed by DNREC was followed, additional evaluations were performed to address all key COPCs, including those generally classified as persistent and bioaccumulative.

At the time when the RI/RA report was submitted, the IRM did not support vegetation. DuPont presumed that the remedy would be implemented in a relatively short period of time. Voluntary vegetative growth has occurred within the last year. DuPont is currently working with DNREC on an enhanced storm water and sediment erosion control plan, which will include an appropriate temporary cover for the pile.

As Schnabel stated, the presence of vegetation is not an issue under either remedial alternative. DuPont agrees that "…the completion of the proposed remedy will reduce/eliminate the direct contact route and therefore the data are sufficient."

Schnabel Statement—Section 2.8, Ecological and Natural Resources Injury

The site, though not a robust wildlife habitat, does support a variety of wildlife. As noted previously, several types of birds and mammals were observed on-site. Ecology and natural resource injury was not discussed except in relation to the risk assessment, which concluded that a capping system would eliminate or reduce direct exposure and off-site migration. This in turn would minimize or eliminate ecological or natural resource injury…It should be noted that during the site visit, we observed several erosion and surface maintenance issues which exposed the IRM to the environment, and potentially the wildlife currently on and passing through the site.

DuPont Comment #13

Ecological receptors were addressed consistent with DNREC requirements, and a natural resource injury assessment is not part of the RI/RA process. At the time when the RI/RA report was submitted, the IRM did not support vegetation. DuPont presumed that the remedy would be implemented in a relatively short period of time. Voluntary vegetative growth has occurred within the last year. However, DuPont agrees that the completion of the proposed remedy will eliminate the exposure route.

After the pile was regraded in 2002, DuPont installed storm water and sediment erosion controls in accordance with DNREC regulations. DuPont inspects these controls on a monthly basis and maintains them as necessary. They continue to function successfully as designed.

Schnabel Statement—Section 2.10, Conclusion

The multiple investigative reports performed on the Hay Road Sludge Drying Site did not provide sufficient information and data to assess the site. Information was haphazardly extracted from prior studies and reports and, because of this the relevant information was not always effectively presented. Similarly, because information was extracted from multiple past reports, the tables summarizing the chemical properties of various media appear to be thrown together in an unorganized manner.

DuPont Comment #14

DuPont believes that the information and data presented in the RI/RA report and supporting documentation (Table 2-1 of the Schnabel report) presents a clear picture of the nature and extent of contamination at the site. The extent of information and data available for the site is comparable and in compliance with the USEPA RI/FS process. Furthermore, DuPont believes that these documents present a clear and scientifically valid evaluation of both the potential transport and fate of certain chemicals present at the site and the potential risk these chemicals present to human health and the environment. DuPont believes that the in-place capping system remedy is the best remedy to protect human health and the environment.

Schnabel Statement—Section 3.2.1.1: Section 2.1 – Introduction

Section 2.1 short circuits the remediation technology evaluation by suggesting that the iron rich material (IRM) can only be treated by two approaches: Containment with institutional controls, and source removal & disposal. No technical justification for this statement is provided in later sections in the FFS.

DuPont Comment #15

DuPont performed an FFS and evaluated two remedial alternatives in detail in accordance with the VCP Agreement scope of work (DNREC, 2002). As DNREC HSCA guidance (1994) states, "Some facilities have contamination problems that point directly to a proven remedial technology before the investigation even begins" (Section 5.2.4, pages 5 through 11).

Schnabel Statement—Section 3.2.1.2: Section 2.2 – Identification of General Remedial Action Alternatives

This section appears to conflict with Section 2.1 in that remedial alternatives beyond the two "presumptive" remedies are presented. DuPont has not provided any technical documentation from prior projects or the literature that the proposed alternatives technically apply to the management of the IRM. As stated above, this list and the possible variations should be larger (possibly closer to 10 candidate technologies/approaches).

DuPont Comment #16

DuPont believes the two presumptive remedies (cap-in-place and removal and disposal) remain the most appropriate. These two technologies have been successfully implemented at similar sites across the United States. In fact, the cap-in-place remedy has been successfully implemented at several sites in Delaware (e.g., Fox Point Park, Joe White Ball Park, former Lewes Boat Yard). The broad remedial action alternative categories were presented in the FFS simply to show how the two presumptive remedies fit into the overall range of remedial actions.

Schnabel Statement—Section 3.2.1.3: Section 2.3 – Identification of Screening of Process Option Technology Types

The identification and screening of site management options for addressing the long term disposition of the IRM are deficient. It is not clear: (1) which of the COC is driving remediation decision making; (2) if there is a hierarchy between the compounds; and (3) what (numerical) remedial targets are assigned for each COC.

DuPont Comment #17

The comments below are DuPont's attempt to clarify the issues listed above.

1. Only COPCs that exceed the DNREC Uniform Risk-Based Remediation Standards are required to be remediated to protect human health and the environment. The FFS RAOs (Section 1.3) make it quite clear that iron, manganese, HCB, and PCBs are the COPCs that require remediation. Those COPCs are also listed in the *DNREC Proposed Plan of Remedial Action* dated December 14, 2004 (DNREC, 2004a).

2. All compounds that require remediation are considered equally, and the numerical remediation targets are the DNREC Uniform Risk-Based Remediation Standards for each compound.
3. Either proposed remedy (once completed) would reduce the public and environmental exposure to below the Uniform Risk-Based Remediation Standards or to the point where no environmental harm would result.

Schnabel Statement—Section 3.2.2.1: Section 3.1 – Detailed Analysis of Alternative 1

If the RFs routinely applied to strength and drainage applications produce FSs on the order of 10 to 20, then the generous FSs applied to GM should be at least of this magnitude or probably higher.

DuPont Comment #18

The concept of RFs is to include into the measured test property of a material those influences that are not included in the test protocol. A typical example is to include a RF for long-term creep into the as-measured laboratory short-term test performance of a geotextile or geogrid. For materials that are adequately simulated in the test protocol (e.g., steel, concrete, soil, rock), RFs are not applied (or the RFs = 1.0 and thus have no effect) to the as-measured test properties. The goal in these traditional construction materials is to simulate their behavior in the laboratory test and then use a (global) factor-of-safety for unforeseen considerations in both design and testing.

Geomembranes fall into this factor-of-safety category. The design should be constructed such that tensile stresses, installation damage, and long-term damage do not occur on the geomembrane by using proper construction quality control/construction quality assurance procedures or by using appropriate protection materials (geotextiles or fine sand soils). Lastly, long-term chemical effects are not a factor via the inherent inertness of HDPE. Thus, all of the conventionally used RFs for geotextiles and geogrids are 1.0 for geomembranes, and thus can be eliminated from consideration in the design/testing process (Koerner, 2007).

Schnabel Statement—Section 3.2.2.1: Section 3.1 – Detailed Analysis of Alternative 1

Peggs (2003) indicates that the maximum operational life of HDPE liners is on the order of 25 years.

DuPont Comment #19

The referenced paper by Peggs *never* states that the maximum operational life of HDPE geomembrane liners is on the order of 25 years. Peggs states "…our practical experience with HDPE geomembranes is limited to about 25 years." In fact, Peggs claims that if high quality geomembrane materials are used in conjunction with good design and quality construction practices, then "an HDPE geomembrane in a MSW [municipal solid waste] landfill should last for about 400 years." The referenced paper by Peggs is provided in Exhibit D.

Schnabel Statement—Section 3.2.2.2: Section 3.2 – Individual Analysis of Alternative 2

It is our opinion that the transportation risk associated with the removal of the IRM is a false dilemma for four main reasons…We consider the inclusion of only one option deficient, *especially as DuPont already transports the currently produced IRM by rail from the Edge Moor facility.*

DuPont Comment #20

DuPont disagrees with Schnabel's opinion that there is any false dilemma. Risk assessments are based on data, not conjecture. Risk assessment and risk management are separate processes, with the former informing the latter. In this instance, evaluating transportation risk associated with the source removal and disposal alternative, which is a valid consideration for choosing among remedies, provides a result showing a higher risk than the capping alternative. This is not an opinion but a reasoned estimate and helps inform the risk management decision. The issues raised in the comments appear to be opinions, which in some instances are irrelevant.

Further, while it might be Schnabel's opinion that inclusion of "only one option" for off-site transport is deficient, it must be recognized that this evaluation was performed under an appropriately approved FFS. As correctly noted in the Schnabel report, "A focused feasibility study considering a limited number of remedial alternatives or the use of a presumptive remedy may be used in lieu of a normal feasibility study with the prior approval of the Department (DNREC)." Hence, there is no need for a wide range of options. To be clear, the FFS evaluated several options to meet the RAOs (summarized in Table 1.2 of the FFS report). Two remedial alternatives received detailed evaluation because the site has a presumptive remedy in the RAOs. The detailed analysis will evaluate those alternatives against 10 criteria specified in the DNREC HSCA regulations:

- ❑ Protection of health, welfare, and environment
- ❑ Compliance with laws and regulations
- ❑ Community acceptance
- ❑ Compliance monitoring requirements
- ❑ Permanence
- ❑ Practicability
- ❑ Restoration time frame
- ❑ Reduction of contamination
- ❑ Long-term effectiveness
- ❑ Short-term effectiveness

While both alternatives would meet the 10 criteria, the recommended remedial action alternative consisting of a multi-layer geosynthetic capping system was favored because of the lower risk associated with implementing the remedy. While transportation risk was a key factor in this decision, timing is another important consideration. Based on the current capacity to incinerate K178 waste, it is likely that it would take significantly longer (years) to remove the material versus capping the material (months).

The Schnabel Report suggests using rail as an alternate to trucking the material. Based on the statistics published by the Federal Railroad Administration (USDOT, 2007), DuPont found that transportation risk via rail versus truck transport is not significantly different. It should be noted that this calculation (see Exhibit E) only considered the transport of materials to an incinerator—not getting the material to the rail line. Hence, DuPont maintains that using rail as an alternate does not materially change the risk management decision.

Schnabel Statement—Section 3.2.3: Concluding Remarks and Recommendations – Remedial Alternative Screening Process

As discussed above, it is our opinion that the initial remedial alternative screening process did not consider a broad range of available remedial technologies, which had they been incorporated into the process may have passed the screening process. The choice of a "presumptive remedy(ies)" resulted in two extreme choices. Additionally, risks were incorporated and evaluated in the screening process that: (1) have previously been accepted by DuPont in its regular operations, and (2) are not normally used in risk assessments.

DuPont Comment #21

DuPont performed an FFS and evaluated two remedial alternatives in detail in accordance with the VCP Agreement scope of work (DNREC, 2002). DNREC approved the FFS approach in the VCP Agreement scope of work (DNREC, 2002). Most regulatory agencies in the United States accept a presumptive remedy approach in an effort to implement site cleanup faster. Generally, two technologies emerge as possible remedies: removal of the waste pile from the site or capping of the waste pile in-place. Should groundwater pollution be a problem based on future monitoring, then remedial technologies to address groundwater impacts would be considered. The technologies listed by Schnabel on page 9 of their report (pump and treat, funnel and gate, and permeable reactive barriers) are used as part of a groundwater remediation effort. The remaining containment technologies mentioned (slurry walls, HDPE cut-off walls, and grout curtains) are also only used to remediate groundwater. The groundwater at the site does not require remediation as it is in a GMZ and not used for potable use; therefore, these technologies were not considered. This GMZ was established by DNREC for the City of Wilmington in 2001.

Schnabel mentions a S/S technology on page 9. Because the IRM was produced by a S/S process, it was already stabilized (i.e., complexed with lime) and solidified (i.e., frame filter press). "Source removal and recycling of the IRM for mineral recovery" is similar in cost to the removal option and also complicated by federal regulatory restrictions on handling the material.

Relative to operational issues, DuPont must transport the currently generated IRM out of business necessity and accepts the associated risks accordingly because there is no other transport option. Relative to remediation issues, DuPont has the option of determining a remedy based on relative risk. The cap-in-place remedy minimizes the risks associated with transportation.

Schnabel Statement—Section 3.2.3: Concluding Remarks and Recommendations – Screened/Selected Remedial Alternatives

The useful life of the capping alternative has not been properly or rigorously established.

DuPont Comment #22

Schnabel's conclusion that Peggs (2003) indicates that the maximum operational life of HDPE geomembranes is on the order of 25 years is incorrect. In fact, the Peggs paper *never* makes this statement. Peggs does, however, state that "our practical experience with HDPE geomembranes is limited to about 25 years." Peggs further states that if high quality materials are used in conjunction with good design and quality construction practices, then "an HDPE geomembrane in a MSW [municipal solid waste] landfill should last for about 400 years."

Geomembranes have been used as lining materials (e.g., caps and base liners) for about 30 years. During this time, "adequate performance has been demonstrated" (Peggs, 2003). Because the track record of geomembranes is only a few decades, the question of useful lifetime is often asked. To estimate the durability and aging of geomembranes, accelerated laboratory testing and modeling are used. These methods use elevated temperatures, elevated stresses, and/or aggressive liquids (i.e., leachate) to accelerate the geomembrane aging process. The Geosynthetic Research Institute and others have conducted extensive research on the lifetime prediction of HDPE geomembranes since the 1980s. They have concluded that HDPE geomembranes have extremely long service lifetimes (i.e., hundreds of years when buried) if good quality materials are used and installed properly (i.e., without damage).

Note that the Geosynthetic Research Institute uses the same laboratory testing and modeling procedures as the entire plastics industry for their geomembrane lifetime prediction work. The plastics industry has a longer track record than the geomembrane industry. For example, the cable shielding industry and the plastic gas pipe industry have been using plastic for more than 50 and 40 years, respectively. The Geosynthetic Research Institute uses the same lifetime prediction procedures for geomembranes as these two major industries.

The geosynthetics industry agrees that geomembrane materials will last a long time and that the most critical element in providing a capping system with a long service life is protecting the geomembrane during installation. Succeeding in protecting the geomembrane during installation involves appropriate engineering design, quality construction practices, and construction quality assurance procedures (i.e., inspection and testing during and after installation).

DuPont plans to prepare a quality engineered design, specify quality construction practices, and use construction quality assurance and construction quality control during the implementation of the DNREC-approved remedy.

Schnabel Statement—Section 3.2.3: Concluding Remarks and Recommendations – Screened/Selected Remedial Alternatives

The offsite disposal alternative evaluation was not conducted in sufficient detail to accurately quantify the costs and risks.

DuPont Comment #23

The document entitled *Remedy Implementation Risk Evaluation – DuPont Cherry Island Facility* was a separate, comprehensive evaluation of the risks associated with implementing the off-site disposal alternative (ENVIRON, 2002). DuPont updated this document in April 2005 per DNREC's request (DuPont, 2005). The updated document considered more details than the typical risk evaluation provided within an FFS document (e.g., dust emission modeling, air concentration estimation and evaluation, estimated manpower requirements for remedy implementation, materials routing and travel distances for remedy implementation, estimation of on-site worker injuries and fatalities, and estimation of off-site transportation-related injuries and fatalities).

The cost estimates for implementation provided in Table 3 (capping remedy) and Table 4 (off-site remedy) of the FFS are of sufficient detail to allow relative determination of the cost of the two alternatives. The overall cost of the off-site disposal alternative remains orders of magnitude greater than the capping alternative.

Schnabel Statement—Section 3.3.1: General Comments

A focused feasibility study considering a limited number of remedial alternatives or the use of a presumptive remedy may be used in lieu of a normal feasibility study with the prior approval of the Department (DNREC). After a review of the in-hand and public record documents, it does not appear that prior approval for DuPont to perform a focused feasibility study was applied for or granted in any formal document.

DuPont Comment #24

DuPont performed an FFS and evaluated two remedial alternatives in detail in accordance with the VCP Agreement scope of work (DNREC, 2002).

Schnabel Statement—Section 3.3.1: General Comments

The FFS submitted by CRG referenced an out-of-date revision of the Delaware HSCA Guidance Manual. The study referenced a 1991 revision versus the latest and correct revision of October 1994 as outlined in the VCP Agreement. Through our correspondence with DNREC, it was established that no 1991 revision exists; therefore, the mistake is believed to be an error carried throughout the document.

DuPont Comment #25

DuPont did reference an out-of date revision of the Delaware HSCA guidance manual; however, the differences between the two guidance documents were subtle and would not have produced different conclusions in the FFS. DuPont has a copy of the 1991 HSCA guidance; it is labeled as “interim” and dated September 1, 1991. DuPont agrees with Schnabel that the 1994 is the more current guidance document.

Schnabel Statement—Section 3.3.2.2.2: Section 2.2 – Identification of General Remedial Response Actions

Although outside the scope of this task, another issue concerns the lack of numeric values for the quantitative RAO. Objectives 2 and 4, referencing Section 1.3.2 Quantitative Remedial Action Objectives, are more qualitative than quantitative. The assignment of finite qualitative goals for the cleanup effort may not be sufficient in order to adequately assess cleanup goals and standards. It is our opinion that the RAO should be reassessed to provide distinct quantitative goals.

DuPont Comment #26

The *DNREC Proposed Plan of Remedial Action* dated December 14, 2004, presents the final RAOs (DNREC, 2004). Three of the five quantitative RAOs have numerical values associated with them. The other two RAOs concern deed restrictions and storm water management to prevent exposure of DM. DuPont believes that these five quantitative RAOs that DNREC approved are sufficient to adequately assess cleanup goals and standards.

Schnabel Statement—Section 3.3.2.2.2: Section 2.2 – Identification of General Remedial Response Actions

Paragraph six of Section 2.3 of the FFS describes the use of a presumptive remedy established in the RAO, thereby limiting the remedial alternatives reviewed to two. A summary analysis of these two remedies as well as Institutional/Engineering Controls is claimed to be provided in Table 3 of the FFS. This table, assumed to mirror Table 5-3 of the Guidance Manual, is not apparently included in the FFS. Table 3 of the FFS is actually a cost analysis of remedial Alternative 1 referenced in paragraph seven. DuPont should provide this table and associated tables.

DuPont Comment #27

The statement is correct that a table similar to Table 5-3 of the guidance manual was not provided in the FFS report. However, its absence does not affect the conclusions of the FFS report. According to the guidance manual, the purpose of the table is to summarize the screening process of the two presumptive remedies. DuPont believes that the detailed written analysis of each of the two remedies provided in Section 3.0 of the FFS report sufficiently discusses each remedy (DuPont, 2004b).

Schnabel Statement—Section 3.3.2.2.4: Section 2.4 – Development of Remedial Alternatives

It is our opinion that Section 2.4 of the FFS is deficient. The requirements' intended purpose, once the alternatives are identified, is to provide a detailed development of these alternatives to aid in the subsequent screening and evaluation of these alternatives…The FFS limits the use of this section to a brief introduction of the two selected remedial alternatives. Partial descriptions of the selected alternatives are included in Sections 3.1.1 and 3.2.1, but not to the extent recommended by the Guidance Manual.

DuPont Comment #28

Because it is a presumptive remedy (per DNREC 1994 HSCA Guidance Section 5.2.4), an extensive development of remedial alternatives is not required. The FFS proceeded directly to a detailed analysis of the alternatives.

Schnabel Statement—Section 3.3.2.3: Section 3.0 – Detailed Analysis of Alternative

The objective of this section is to present the relative advantages and disadvantages of the selected alternatives. This is completed by using the alternatives against ten criteria DNREC uses to select a preferred alternative…However, a comparison of the alternatives for each criterion was not documented within the FFS.

DuPont Comment #29

Sections 3.1 ("Detailed Analysis of Alternative 1 – Capping and Institutional/Engineering Controls") and 3.2 ("Individual Analysis of Alternative 2 – Source Removal and Disposal) of the FFS report provide a separate comparison of each alternative to the 10 DNREC criteria (DuPont, 2004b). A separate comparison of each alternative was thought to be less confusing to the reader of the FFS report.

Schnabel Statement— Section 3.3.2.3.1: Section 3.1 – Detailed Analysis of Alternative 1 – Capping and Institutional/Engineering Controls

- *<u>Compliance with laws and regulations</u>: Insufficient information is provided in this section. The RCRA Subtitle C, Hazardous Waste Regulations referenced would not be the only regulations or permits required under this remedial alternative.*

  DuPont Comment #30
  For the cap-in-place alternative, the FFS appropriately identified RCRA Subtitle C as the major regulatory reference for this remedial alternative. Other permits needed to construct this remedy include a City of Wilmington Building Permit and a Sediment and Stormwater Permit. DuPont would apply for and follow the requirements of all permits and regulations that are applicable to the construction of this remedy.

- *<u>Community acceptance</u>: The information for this section was not attainable at the time the report was filed; therefore, it should be considered now.*

  DuPont Comment #31
  Public hearings and meetings (as well as this public comment period) allow the community to communicate directly with DNREC their acceptance, questions, or concerns about the proposed remedies. DuPont has provided the public with as much information as possible about the cap-in-place alternative and is looking forward to continuing with communications efforts.

- *<u>Remediation monitoring</u>: …No mention of inspection methods or frequencies is addressed other than the ground water sampling requirements referencing Section 1.3.2. The Guidance Manual suggests considering the consequences of a failed remedy in this section; however, this was not evaluated.*

  DuPont Comment #32
  For the cap-in-place alternative, an operation and maintenance plan (required by DNREC as part of the remedial design) would be developed and would discuss inspection methods and frequencies.

- *<u>Permanence</u>: …This section discusses the permanence of the cap, but fails to address the multiple media or relationship to the COC.*

  DuPont Comment #33
  With a cap-in-place remedy, all of the waste material (including the COPCs that exceed the DNREC Uniform Risk-Based Remediation Standards) would remain in-place and would not receive additional treatment beyond the stabilization that had already been performed prior to depositing the IRM at the Hay Road site.

- *<u>Restoration time frame</u>: A sufficient implementation schedule for this remedial alternative was not presented.*

  DuPont Comment #34
  Once construction begins, a time frame of six months for implementation of the capping alternative was provided (Section 3.1.8, page 14; DuPont, 2004b). The remedial design report is the appropriate document to present a detailed construction schedule.

- *<u>Long-term effectiveness</u>: This section discusses the contamination remaining on site and the associated risk, and the permanence of the cap, but fails to address the multiple media or relationship to the COC… it fails to address the difficulties associated with this long-term operation and maintenance program, the potential for the remedy's failure, and the associated risks.*

  DuPont Comment #35
  With a cap-in-place remedy, all of the waste material (including the COPCs that exceed the DNREC Uniform Risk-Based Remediation Standards) would remain in-place, would be covered, and would not receive additional treatment beyond the stabilization that had already been completed. The potential difficulties associated with the long-term operation and maintenance of the remedy would be addressed through monthly site inspections. Issues to be observed and addressed would include localized settlement, vegetation establishment, and storm water and sediment erosion controls. DuPont would verify the long-term effectiveness of the cap-in-place alternative through a groundwater monitoring program. These items would be addressed in a postclosure monitoring program.

- *<u>Short-term effectiveness</u>: … it fails to discuss the ease or availability of mitigation measures.*

  DuPont Comment #36
  Mitigation measures (e.g., storm water and sediment erosion controls) for the cap-in-place alternative are typically addressed in a remedial design report, not in an FFS report.

- *<u>Cost</u>: There is no guidance provided for the assessment of the capital and operation maintenance cost effectiveness.*

  DuPont Comment #37
  For the cap-in-place alternative, the cost estimates were developed by DuPont and URS Corporation based on over 20 years of experience in remediation projects.

Schnabel Statement—Section 3.3.2.3.2: Section 3.2 – Detailed Analysis of Alternative 2 – Source Removal and Disposal

- *<u>Community acceptance</u>: The information for this section was not attainable at the time the report was filed; therefore, it should be considered now.*

DuPont Comment #38
Public hearings and meetings (as well as this public comment period) allow the community to communicate directly with DNREC their acceptance, questions, or concerns about the proposed remedies. DuPont has provided the public with as much information as possible about the source removal and disposal alternative and will continue with communications efforts.

- *Permanence: This section sufficiently describes the permanence of the remedy. It does not however discuss the residual contamination after the IRM has been removed.*

DuPont Comment #39
The presence of DM at the site (and at all DM disposal sites) along the Delaware River would remain a concern after removal of the IRM under this possible remedial alternative. Because the iron and manganese levels in the DM are above DNREC Uniform Risk-Based Remediation Standards, a cover of imported soil would be placed over the DM.

- *Technical practicability: The technical practicability has not in our opinion been sufficiently evaluated.*

DuPont Comment #40
As DuPont states on page 16, Section 3.2.7 of the FFS report "The excavation, transportation and disposal technologies involved in implementation of this remedy are all conventional in the sense they are frequently used at contaminated sites" (DuPont, 2004b). DuPont is unclear what parameters need to be evaluated to determine the technical practicability of excavating, transporting, and disposing of the material off-site.

- *Restoration time frame: A sufficient implementation schedule for this remedial alternative was not presented.*

DuPont Comment #41
A time frame of 12 months to implement the source removal and disposal alternative was provided in Section 3.2.8 on page 16 of the FFS report (DuPont, 2004b). Given the potential challenges with identifying appropriate treatment capacity (incineration) for the IRM, the actual implementation time would be several years. The remedial design report is the appropriate document to present a detailed construction schedule.

- *Long-term effectiveness*: *The long-term effectiveness of the remedy is not sufficiently addressed.*

DuPont Comment #42
DuPont believes the statement made in Section 3.2.10 (page 16) of the FFS report sufficiently addresses the long-term effectiveness of the source removal and disposal alternative: "Because this alternative completely removes the IRM, the source no longer exists. Therefore, this option is effective for the long-term" (DuPont, 2004b).

- *<u>Cost</u>: There is no guidance provided for the assessment of the capital and operation maintenance cost effectiveness.*

  DuPont Comment #43
  For the source removal and disposal alternative, the cost estimates were developed by DuPont and URS Corporation based on over 20 years of experience in remediation projects.

Schnabel Statement—Section 3.3.2.4: Section 4.0 – Recommendation of Preferred Alternative

DNREC does not provide guidance for the selection of the preferred alternative remedy other than the selection criteria above. Documentation of the comparative analysis process should be provided…This section's only reference to a comparison made between the two alternatives is a cost-effectiveness decision. It is our opinion that a full evaluation of criteria should be assessed and presented.

DuPont Comment #44

DuPont believes that the discussion of the criteria provided in the FFS report provides sufficient evaluation and explanation to allow DNREC to render an informed decision as to the most appropriate remedial action for the site. In fact, DNREC reviewed the FFS against its own regulations and approved the FFS on June 23, 2004 (DNREC, 2004b).

Schnabel Statement—Section 2.3: Hydrogeology

The presented hydrogeology information is deficient to sufficiently characterize the conditions.

DuPont Comment #45

DuPont believes that it has developed an adequate understanding of potential contaminant migration in the groundwater flow regime beneath the site, including the interaction of that groundwater with the surface water bodies, for the purposes of remedy selection.

Extensive geotechnical investigations have been conducted at the site, including multiple studies in the early 1970s, Cell 2 investigations (1977), Cell 3 investigations (1978 through 1979), Cell 4 investigation (1990), landfill closure investigation (1992), and the pre-design investigation (2000). Exhibit A illustrates the numerous soil borings, test pits, wells, and piezometers that have been employed to understand the site subsurface. DuPont is aware that heterogeneities may influence the bulk permeability of a unit. However, sand beds or laminations within the DM were thin and not laterally correlative, indicating that they are likely discontinuous lenses rather than extensive flow pathways.

As Schnabel states, permeability/hydraulic conductivity data are available for several locations west of the IRM storage pile at various depths. Boring logs are also available for locations across the site, both in the areas where the permeability data were collected and under the IRM pile (see Exhibit A). The logs of the 14 borings within or on the margin of the footprint of the IRM pile indicate that the materials beneath the pile are comparable to those used for the permeability analyses. The hydraulic conductivity value of 4.6×10^{-2} cm/sec cited by Schnabel was obtained from the Shallow Sand unit in the western portion of the site, not from the DM that underlies the IRM storage area. The highest vertical hydraulic conductivity measured on any of the DM at the site was 1.1×10^{-5} cm/sec.

Schnabel Statement—Section 2.3: Hydrogeology

Section 2.3 does not present the advection-diffusion-reaction equation (ADRE) for solute transport. Accordingly, the "ground water" movement does not properly account for the (additional) diffusive transport which is an important component of solute transport in fine-grained media such as IRM and DM.

DuPont Comment #46

Section 2.3 of the RI/RA report ("Hydrogeology") describes the hydrogeological framework of the groundwater movement, and, as such, presents the appropriate equation for determining the average linear velocity of groundwater flow (DuPont, 2004a). Solute transport is addressed in Section 4.1.4 of the RI/RA report, under the subheading of "Groundwater-Surface Water Discharges" (DuPont, 2004a).

The AT123D model discussed in Section 4.1.4 addresses the components of the ADRE by accounting for advection, dispersion, and adsorption (ENVIRON, 2003). Although the AT123D model is able to account for contaminant degradation, DuPont made the very conservative assumption that no degradation will occur (ENVIRON, 2003).

Schnabel Statement—Section 2.3: Hydrogeology

Importantly, as presented in DuPont's documents, there are areas to the west of the IRM pile where hydraulic conductivity of the dredged material is on the order of 1 x 10^{-2} cm/sec (see DuPont's June 9, 2000, Proposal for Remedial Action). Although, hydraulic conductivity data are not available for the dredged material underneath the IRM pile, presence of sand lenses observed during the previous drilling in the area, and practical experience suggests that higher hydraulic conductivities are also expected within the footprint of the IRM pile. Using a hydraulic conductivity of 1 x 10^{-2} cm/sec, ground water seepage velocities are approximately four orders-of-magnitude higher than that those calculated by DuPont's consultant; correspondingly, chemical transport would be similarly accelerated.

DuPont Comment #47

The RI/RA report presented hydraulic conductivity data obtained from Shelby tubes collected from the DM in the landfill area (DuPont, 2004a). Although these locations were not within the footprint of the proposed remedy, DuPont believes they are representative of the DM beneath the IRM based upon similarity in lithology reported on boring logs. Additional information is provided in Exhibit A.

Schnabel Statement—Section 5.1.2: Section 2.7 – Ecology

The sensitive ecological receptors as presented by DuPont's consultant are deficient to sufficiently characterize the ecological risk from the IRM pile. For example, during a site reconnaissance visit conducted by staff from LRM, Schnabel, DuPont, and DNREC in July 2006, substantial vegetative growth was noted on the IRM which serves as a source of food for wildlife. Correspondingly, avian species and terrestrial wildlife, including a red fox, were observed foraging on the IRM pile. DuPont should necessarily include a formal habitat study and, if applicable, include an assessment of potential exposure to endangered and/or special-status species relevant to the region.

DuPont Comment #48

As correctly noted, the IRM storage area is not a "robust wildlife habitat." Consistent with standard risk assessment protocols, a site conceptual model was used to define all relevant COPCs, exposure pathways, and receptors. DuPont agrees with Schnabel's conclusion earlier in Section 2.5.1 that "… the completion of the proposed remedy will reduce/eliminate the direct contact route, and therefore the data are sufficient," and reiterated in Section 2.6.4: "this would not be an issue under either remediation option."

DuPont disagrees with the need for a more detailed habitat study for the purposes of the remedial investigation because such an exercise will not change the risk management decision.

Schnabel Statement—Section 5.1.3: Section 3.1.1 – Iron Rich

As discussed elsewhere, DuPont and DuPont's consultant Environ appear to have not used or cited the correct property data for hexachlorobenzene (HCB) and other compounds in their evaluations and assessments. A frequently used source for chemical property data is USEPA/600/8-90/003 which indicates that the solubility limit of HCB is 6 x 10^{-3} mg/L and the octanol-water partitioning coefficient OW is 1.75 x 10^{5}. The values provided by Verschveven (1988) are in general agreement with these values…

DuPont Comment #49

The solubility value for HCB given in the Schnabel Report is identical to that given in the cited reference, the USEPA Soil Screening Guidance (Attachment C, page C-3; USEPA, 1996). Given the discrepancy between the values reported in different USEPA documents, the solubility value may be incorrect. However, because the acceptable levels for HCB (based on screening) remain larger than the smaller solubility of 6.2 µg/L given, the conclusions of the analysis (i.e., the presence of this compound in the leachate will not result in any exceedance of risk-based surface water criteria) would not change.

Schnabel Statement—Section 5.1.3: Section 3.1.1 – Iron Rich

Table 5-2 indicates that given the soil concentrations of HCB detected in the IRM, free (pure) product of HCB ranging between approximately 10 and 90 liters/m^3 of IRM is predicted. The main conclusion to be drawn from this simulation is that significant quantities of HCB exist in the IRM, and the soil concentrations point to the presence of free product…Table 5-2 repeats the same general calculation, but is based on the HCB soil concentrations in the dredged material (DM)…NAPL is again predicted to occur for the same range of porosities simulated…It is therefore incumbent on DuPont to better characterize the IRM and the DM underlying the stockpile and DuPont IRM site to provide more definitive information regarding the potential presence of DNAPL.

DuPont Comment #50

DuPont assumes that the first reference to Table 5-2 above actually refers to Table 5-1. This assumption is based on the table title and content.

Schnabel draws their conclusions based on estimates of the volume of pure phase HCB in soil (IRM or DM), which was calculated using the measured HCB concentrations and an analytical model of HCB partitioning in soil. While the concept of chemical partitioning between constituents in the pure phase, water phase, sorbed phase, and vapor phase that Schnabel refers to is valid, they did not provide the corresponding equations used to arrive at their estimates, and the estimates and conclusions are incorrect. The calculations and discussion presented in Exhibit F clearly indicate the following:

- HCB is not present in the soil (IRM or DM) in significant amounts as a separate pure phase, either as a DNAPL or as a solid organic compound. Using the same basic assumptions, the estimates presented by Schnabel have been found to be overestimated by a factor of at least 1,000 apparently due to a unit conversion error. Based on the conservative assumption that all measured HCB was present as a pure phase, calculations show there would only be 0.010 to 0.090 liters (2 to 18 teaspoons) in 1 cubic meter of IRM.
- Even ignoring adsorption, downward migration of HCB has not and will not occur because any pure phase HCB would be present as a solid that cannot migrate. The melting point of HCB is 231°C (http://www.atsdr.cdc.gov/toxprofiles/tp90.html); therefore, at normal temperatures, any pure phase HCB would be present as a solid.
- Any HCB present in IRM is strongly adsorbed to the carbonaceous IRM due to HCB's very high organic carbon partition coefficient. Results of past TCLP analysis of IRM for HCB support ATSDR's statement that HCB is "generally considered immobile with respect to leaching" (http://www.atsdr.cdc.gov/toxprofiles/tp90.html).

Based on the facts above, further characterization of the IRM and DM for the potential presence of DNAPL is not warranted.

Schnabel Statement—Section 5.1.4.1: Potential Pathways of Exposure

The pathways of exposure identified by DuPont for the IRM staging area pile are deficient. DuPont ignored potential onsite ecological receptors (see above - avian and terrestrial wildlife were observed to be foraging on the IRM during a recent site visit) that may be exposed to the existing vegetation on the IRM pile for the direct exposure pathway. Exposure to chemicals from windblown deposition of particulates from the IRM pile to potential downwind offsite receptors has not been considered in the RA. Both of these pathways should be included in the revised risk assessments.

DuPont Comment #51

DuPont disagrees with these statements. As noted in the Schnabel Report, "The exposure pathways that were considered in DuPont's RI/RA report include: direct contact, air/wind dispersion, ground water, and surface water."

Consistent with standard risk assessment protocols, a site conceptual model was used to define *all relevant* COPCs, exposure pathways, and receptors. At the time when the RI/RA report was submitted, the IRM did not support vegetation. DuPont presumed that the remedy would be implemented in a relatively short period of time. Voluntary vegetative growth has occurred within the last year. DuPont is currently working with DNREC on an enhanced storm water and sediment erosion control plan, which will include an appropriate temporary cover for the pile. As correctly noted, the IRM storage area is not a "robust wildlife habitat." DuPont agrees with Schnabel's conclusion earlier in Section 2.5.1 that "…the completion of the proposed remedy will reduce/eliminate the direct contact route, and therefore the data are sufficient," and reiterated in Section 2.6.4: "this would not be an issue under either remediation option."

For the air medium, the Schnabel Report states in Section 2.5.2 that "It is our opinion that the information presented within the submittals is sufficient." Furthermore, page 9 of Appendix A of the Schnabel Report states: "The risk assessment was conducted consistent with DNREC's Remediation Standard Guidance Document Under the Delaware Hazardous Substance Cleanup Act, dated December 1999 (DNREC, 1999). Based on existing and intended land use at the site, the risk assessment was conducted to estimate total cumulative risk of exposure to COPCs from affected media (IRM and dredged material) for on-site industrial workers and was conducted in accordance with the DNREC guidance."

While evaluation of wind-blown material is not part of the DNREC requirements for the risk assessment and was not considered complete because of the protective cover, this pathway was extensively evaluated as follows:

Title	Brief Description	Summary/Conclusion
Cherry Island Staging Area Potential Historic Release Assessment, DuPont, Nov 2001, Sept 2002, Dec 2003	• This report was developed as a refined evaluation of the screening level assessment of the uncovered pile provided in April 2001. • Surface runoff and air deposition were modeled under reasonable worst case and maximum worst case conditions. • Estimates of WHO-TEQ for dioxins, furans, and coplanar PCBs that might result in the Delaware River and Shellpot Creek were derived. • A screening level risk evaluation via fish consumption was performed.	• Preliminary evaluation results of this refined assessment were shared with Rick Greene (DNREC on 8/28/01) and his comments and suggestions were incorporated. • Estimated concentrations in the adjacent water bodies resulting from the uncovered pile were not above the ambient water quality criteria. • Cumulative risks were calculated to be approximately an order of magnitude below *de minimus* level (i.e., 2.0×10^{-7} vs. 1.0×10^{-6} risk) for the reasonable worst case and well within the acceptable risk range of 10^{-4} to 10^{-6} and only marginally above the *de minimus* level (i.e., 1.8×10^{-6} vs. 1.0×10^{-6}) for the maximum worst case. • Further, when the maximum calculated LADD for dioxin-like materials as WHO-TEQ (1.8×10^{-12} mg/kg-day) from these computations is compared to background levels (0.59×10^{-9} mg/kg-day) of dioxin as WHO-TEQ, the estimated doses are expected to contribute less than 1% to background (0.30%). As such, the potential contribution of past activities is not considered significant.
Remedy Implementation Risk Evaluation, DuPont Cherry Island Facility, ENVIRON, April 2002, April 2005	• Comparative risk of capping versus excavation (and off-site disposal or incineration) during remedy implementation was performed. • Updated report includes hypothetical worst case off-site community exposures, construction risk, and	• The calculated lifetime cancer risk and chronic noncancer HI values for hypothetical off-site exposures are both approximately 50-fold higher under the excavation alternative than under the capping remedy. The calculated subchronic HI for the excavation alternative is approximately 20-fold higher than the

	transportation risk.	capping remedy.

Schnabel Statement—Section 5.1.4.2: Ground Water Surface Water Discharges

DuPont's consultant has ignored the potential presence of sand lenses in the dredged material and applied arbitrary dilution factors (to simulate mixing of ground water with the surface water). These arbitrary and incorrect assumptions have resulted in increasing chemical cleanup levels for both the IRM and the dredged material; DNREC should reject these assumptions and the cleanup levels should be accordingly recalculated by DuPont's consultant.

DuPont Comment #52

Logs are available for 14 previous (historical) borings located within or on the margin of the footprint of the IRM pile [DB-2A, TB-30 (well 30), TB-105, TB-106, TB-107, TB-108, W-29, W-32, W-33, W-37, W-40, W-46, W-47, and W-48]. The logs for all of these borings (see Exhibit A) indicate silty-clay/clayey-silt from the surface to a depth of 13 to 22 feet bgs. Although some of these logs note the presence of sand lenses within the DM, in nearly all cases, the depth to the shallowest sand lens is greater than 10 feet, and there is no indication that any sand lenses are continuous or interconnected.

The selection and derivation of dilution factors referred to as "arbitrary" are detailed in Section 4.1.4 of the RI/RA report (DuPont, 2004a), as well as the ENVIRON (2003) report. The attenuation factor AF2 was used to address the mixing of groundwater with surface water and was estimated as the ratio of surface water flow to groundwater flow for evaluating protection of human health. In evaluating aquatic species, AF2 was conservatively set at 10 to account for the possibility that some species (e.g., benthic organisms) may be exposed after only limited mixing of groundwater and surface water occurs (see an additional explanation in DuPont Comment #53b).

ENVIRON acknowledged the importance of conductivity, stating "horizontal hydraulic conductivity in the saturated zone is a key parameter in the groundwater modeling." However, given the conservative assumptions used in the modeling, variations in hydraulic conductivity over the observed range of 10^{-7} to 10^{-5} cm/sec would not change the conclusions of the risk assessment.

Schnabel Statement—Section 5.1.4.2: Ground Water Surface Water Discharges

Additional specific comments are included in Appendix A. They should be addressed by DuPont, and the risk assessments should be revised accordingly.

DuPont Comments #53a and #53b

Appendix A comments are listed below after the Schnabel statement.

Potential Ecological Hazards From COCs Contained in the IRM Pile, Appendix A, p. 19

In the RI/RA, a value of 1.7E-05 cm/sec was used as the hydraulic conductivity of the shallow groundwater zone within the dredged material. A wider range of values (4.3E-6 cm/sec to 4.6E-02 cm/sec) is reported in soil borings/wells to the west of the IRM pile. DuPont should collect additional data underneath or in the immediate vicinity of the IRM pile.

DuPont Comment #53a

DM beneath the site was hydraulically placed, allowing fine-grained material to achieve low permeability after dewatering (DuPont, 2004a). To estimate the horizontal hydraulic conductivity, $1.7x10^{-5}$ cm/sec was selected assuming a horizontal to vertical anisotropy ratio of 10:1 for the DM. This anisotropy ratio ranges from conservative to typical for layered formations (Freeze and Cherry, 1979). ENVIRON acknowledged the importance of conductivity in its report, stating “horizontal hydraulic conductivity in the saturated zone is a key parameter in the groundwater modeling.” However, given the conservative assumptions used in the modeling, variations in hydraulic conductivity over the observed range of 10^{-7} to 10^{-5} cm/sec would not change the conclusions of the risk assessment. Additional information is provided in Exhibit A.

Potential Ecological Hazards From COCs Contained in the IRM Pile, Appendix A, p. 19
Attenuation factors (AF2) used to simulate the dilution of groundwater in the surface water is inconsistent with the approach typically recommended by agencies.

DuPont Comment #53b

Schnabel recommends that “estimated concentrations in groundwater for each COPC at the point of groundwater discharge to surface water are directly (i.e., without dilution) compared to applicable water quality data. Use of arbitrary dilution factors without appropriate references and/or justification is considered inappropriate.”

The dilution factors presented in the report are not “arbitrary” as suggested by Schnabel. In evaluating human exposures though fish consumption, it would be unrealistic to assume that fish will be continuously exposed throughout their lives to impacted groundwater without any dilution by surface water. Because the majority of edible fish are expected to spend most of their lives in the Delaware River rather than Shellpot Creek, they would be exposed most of the time to highly diluted groundwater. The AF2 values for human exposures were based on mass balance, which has been extensively used to estimate the effect of mixing on discharges. The choice of flow rate for the Delaware River, as stated in the ENVIRON report, is “consistent with the basis for ambient quality criteria developed by DRBC (1995).” This mixing method has also been used to evaluate the impacts of contaminated groundwater discharges from the Potts Property Site to the Christina River, one mile south of the IRM site (http://www.dnrec.state.de.us/DNREC2000/Divisions/AWM/SIRB/Misc/Attachment%20Potts%20Property.pdf). DNREC has previously accepted this method (DNREC, 2000).

The AF2 value of 10 used to assess ecological exposures is consistent with the approach used by the USEPA for evaluating discharge of contaminated groundwater into surface water under the RCRA Corrective Action Environmental Indicators program. This more conservative AF2 was used because certain aquatic species (e.g., benthic organisms) may be exposed to COPCs in sediment pore water in the area of groundwater discharge before additional mixing has occurred.

As noted in the report, this AF2 value is considered conservative because tidal mixing will reduce the concentration of COPCs in groundwater before it discharges to the surface water.

Schnabel Statement—Section 5.1.5.1: Cleanup Standard Option for Human Health

Average total TEQ levels in terms of 2,3,7,8-TCDD are 1,016 parts per trillion (ppt), which exceed DNREC's 2,3,7,8-TCDD threshold of 40 ppt. DNREC currently does not have a TEQ action level for dioxin and dioxin-like compounds, and may follow Region III EPA guidance (fax correspondence from DNREC, dated December 13, 2006). In a 1998 document (Office of Solid Waste and Emergency Response (OSWER) Directive 9200.426), USEPA recommends a TEQ action level of 5,000 to 20,000 ppt for dioxin and dioxin-like compounds. The average TEQ value (1,016 ppt using the 2005 WHO TEFs) in IRM is below the current commercial/industrial threshold. Provided DNREC establishes a TEQ action level consistent with current USEPA standard, and the new dioxin and dioxin-like compounds analytical data to be collected from IRM (see data gap discussion elsewhere) is less than the USEPA commercial/industrial threshold, human health risk from direct exposure to these compounds contained in the IRM is not anticipated to be significant (see Appendix A - Attachment 1).

DuPont Comment #54

The Schnabel Report correctly states that the "USEPA recommends a TEQ action level of 5,000 to 20,000 ppt for dioxin and dioxin-like compounds" and that "The average TEQ value (1,016 ppt using the 1998 WHO TEFs and 1,153 ppt using the 2005 WHO TEFs) in IRM is below the current commercial/industrial threshold." DuPont agrees with the conclusion that "human health risk from direct exposure to these compounds contained in the IRM is not anticipated to be significant." As noted above, these conclusions do not change because of the newer proposed TEFs. DuPont submitted an evaluation of the proposed TEFs to DNREC in August 2006 (DuPont, 2006).

It should be clarified that the USEPA Dioxin Directive (USEPA, 1998), these values are "should also be used as starting points in setting soil cleanup levels at RCRA corrective action sites" not necessarily an action level.

Also, it should be reiterated that 2,3,7,8-TCDD was not detected, at detection limits less than the appropriate screening level of 40 ppt 2,3,7,8-TCDD, not TEQ. Nevertheless, all risk assessments evaluated the risk associated with dioxins/furans/PCBs on a TEQ basis. It is concluded that risk were *de minimus*.

Schnabel Statement— Section 5.1.5.2: Ecological Risk Assessment

The identified pathways of exposure in the ERA are not complete. As discussed above, the onsite direct exposure pathway should be considered by DuPont's consultant, and the ERA should be revised accordingly. For the surface water exposure scenario, the exposure point concentrations resulting from chemical transport from IRM and the dredged material should be reevaluated for comparison with existing DNREC standards for aquatic species (see comments in Section 5.1.4.2 above and in Appendix A -Attachment 1), and the excess human carcinogenic risk as a result of consumption of impacted fish should be recalculated.

DuPont Comment #55

Consistent with standard risk assessment protocols, a site conceptual model was used to define *all relevant* COPCs, exposure pathways, and receptors. At the time when the RI/RA report was submitted, the IRM did not support vegetation. DuPont presumed that the remedy would be implemented in a relatively short period of time. Voluntary vegetative growth has occurred within the last year. DuPont is currently working with DNREC on an enhanced storm water and sediment erosion control plan, which will include an appropriate temporary cover for the pile. As the Schnabel Report correctly notes, the IRM storage area is not a "robust wildlife habitat." DuPont agrees with Schnabel's conclusion earlier in Section 2.5.1 that "… the completion of the proposed remedy will reduce/eliminate the direct contact route, and therefore the data are sufficient" and reiterated in Section 2.6.4: "this would not be an issue under either remediation option."

Schnabel Statement—Section 5.1.5.2: Ecological Risk Assessment

Calculated carcinogenic risk for dioxin and dioxin-like compounds (2.0 x 10^{-7} to 1.8 x 10^{-6} using 1998 WHO TEFs and 2.27 x 10^{-7} to 2.04 x 10^{-6} using 2005 WHO TEFs) was within the acceptable risk range of 1.0 x 10^{-6} to 1.0 x 10^{-4}. However, for dioxin and dioxin-like compounds, excess carcinogenic risk calculated by DNREC staff from existing analytical data of fish tissue samples collected from Shellpot Creek (at Hay Road) were on the order of 1.1 x 10^{-3} to 2.1 x 10^{-5} (2001 DNREC Internal Presentation). In addition to the dioxin contribution from the IRM pile, background dioxin levels in sediment may be contributing to the higher risk levels calculated using the fish tissue samples. Unless a presence of high background dioxin levels is established in sediments in the vicinity of the site and surrounding areas, a reassessment of DuPont's approach (and modeling) conducted to estimate the exposure point concentrations and subsequent excess carcinogenic risk is necessary to accurately estimate the carcinogenic risk as a result of exposure of fish (and subsequently humans) to dioxin-impacted sediments.

DuPont Comment #56

There is a significant background level of dioxins that can originate from a variety of natural and anthropogenic sources. Sediment data collected by DuPont and fish tissue data collected by DNREC suggest that DuPont is not a significant contributor of dioxins to the creek. The total DuPont contribution represents less than 0.1% of the total dioxin/furan toxic equivalents present in the fish tissue. This has been communicated to DNREC (DuPont, 2002).

The conclusions of the Shellpot Creek watershed screening assessment are as follows:

- IRM has a distinct distribution pattern of both PCBs and dioxin/furan congeners.
- The principal sources of both PCBs and dioxins exist in Shellpot Creek above Hay Road.
- The data suggest that IRM may contribute to the nonachlorobiphenyl and decachlorobiphenyl concentrations in lower Shellpot Creek. These homologs make up less than 1% of the total PCB content found in the fish tissue from Shellpot Creek.

- The data suggest that IRM may contribute to the OCDF concentrations in lower Shellpot Creek. These congeners make up less than 0.01% of the total dioxin/furan TEQ found in the fish tissue from Shellpot Creek.

Schnabel Statement—Section 5.1.6: Section 7.0 – Proposed Remedial Action Objectives

The following problems are evident in the DuPont's proposed quantitative RAOs. The statement of the 4th bullet which reads "prohibiting the withdrawal of ground water for other than environmental monitoring purposes...," precludes DuPont from using continuous and/or pulsed ground water pump-and-treat, or any other ground water removal scheme to mitigate against ground water contamination, once detected, and/or documented. Once the ground water is contaminated, corrective action involving any form of ground water manipulation appears completely precluded by the proposed RAO. DNREC should reject this RAO. The last portion of the 5th bullet reads: "the maximum concentrations allowed in ground water will be 726,787 mg/L for iron, 242,262 mg/L for manganese and 1.9 mg/L for hexachlorobenzene."

DuPont Comment #57

DNREC approved this RAO because the standard wording under the DNREC-SIRB UECA specifies that "No groundwater wells shall be installed, and no groundwater shall be withdrawn form any well on the Property without the prior written approval of DNREC-SIRB." If DNREC deems, at a later time, that groundwater remediation (e.g., pump and treat) is needed, DNREC will likely grant DuPont permission to withdrawal the water.

Schnabel Statement—Section 5.1.6: Section 7.0 – Proposed Remedial Action Objectives

The RAO of 1.9 mg HCB/L roughly corresponds to a droplet on the order of 12 mm diameter migrating offsite in every liter of water. DNREC should reject this RAO.

DuPont Comment #58

This RAO calculation (DuPont, 2004a) was approved by DNREC and is protective of groundwater discharging to surface water. Schnabel incorrectly states that the RAO of 1.9 mg HCB per liter of water roughly corresponds to a HCB droplet of approximately 12 mm in diameter. Firstly, it should be noted that the calculated size of an equivalent droplet is intended to help visualize the mass of HCB; HCB in the groundwater will not exist as individual, mobile droplets due to its solid state at temperatures below 230°C (http://www.atsdr.cdc.gov/toxprofiles/tp90.html). Rather, it can be present in groundwater in dissolved-phase form, albeit at very low concentrations (i.e., less than the solubility limit of 0.006 mg/L). Secondly, based on the density of HCB (approximately 2 g/cm^3), the total mass of dissolved HCB in water with a concentration of 1.9 mg HCB/L is equivalent to a droplet that is 1.2 mm in diameter, not 12 mm. Regardless, this droplet equivalency has no bearing on the validity of the RAO because individual droplets are not present. The RAO was justly approved by DNREC because it is based on an appropriate scientific model of the fate and transport of HCB in groundwater.

Schnabel Statement—Section 6.3.1: Dioxins

DuPont's responses to the dioxin questions at the hearings focused on several of the more notable dioxins, but did not provide sufficient detail regarding the overall concentrations and *potential impact of dioxin at the site…We believe that DuPont should generate a summary document that consolidates all of the existing dioxin data for all media, and provides an overview of the dioxin types, concentrations, volumes and relationships to US EPA and DNREC regulatory limits for both soil and ground water.*

DuPont Comment #59

DuPont provided all data related to dioxins to DNREC and has used these data consistently for all reports. A summary of all submissions was provided in June 2005 (DuPont, 2005). DuPont does not believe that additional documentation is required. As Schnabel correctly notes in 5.1.5.1 and Appendix A, "USEPA recommends a TEQ action level of 5,000 to 20,000 ppt for dioxin and dioxin-like compounds" and "the average TEQ value (1,016 ppt using the 2005 WHO TEFs) in IRM is below the current commercial/industrial threshold." DuPont agrees with the conclusion that "human health risk from direct exposure to these compounds contained in the IRM is not anticipated to be significant."

Schnabel Statement—Section 6.3.4.2: Arsenic

A problem we encountered in evaluating arsenic data for the site is that it is scattered in various reports, and very little of this data has been consolidated in summary tables for ease of evaluation by the public. Also the few consolidated tables provided in various documents have not been updated to provide the correct arsenic action level. It is our opinion that this data should be updated, consolidated, and made available to the public.

DuPont Comment #60

DuPont used the lower DNREC Uniform Risk-Based Remediation Standards action level of 11 mg/kg for arsenic in the RI/RA instead of the new (pending) level of 23 mg/kg (DuPont, 2004a). While additional TCLP results for arsenic in the IRM are provided in documents other than the RI/RA report, only the comparison of the total arsenic result to the DNREC Uniform Risk-Based Remediation Standards is meaningful. One of the three sample results exceeded the DNREC standard for arsenic (14.9 mg/kg vs. 11 mg/kg); hence, arsenic is considered a COPC that will be addressed as part of the remedy.

Schnabel Statement—Section 6.3.4.3: Ground Water and Surface Water

During the hearings and in subsequent submittals, DuPont provided data on several COC from Shellpot that were analyzed from samples collected upstream and adjacent to the project site. This data, although not conclusive, indicate a possible source upstream and upgradient of the project site. It is our opinion that this information did not fully address this concern, and we recommend that the data be consolidated in a summary report regarding this issue.

DuPont Comment #61

Although this information does not have an impact on the selected remedy, DuPont would be willing to assist DNREC in compiling the needed data.

Schnabel Statement—Section 6.3.4.3: Ground Water and Surface Water

It is Schnabel's opinion that the documents reviewed and the data presented at the hearings do not adequately address the current conditions, nor the long term potential of contaminants migrating from the IRM to the ground water, and then to the surface water.

DuPont Comment #62

DuPont believes that it has developed an adequate understanding of potential contaminant migration in the groundwater flow regime beneath the site, including the interaction of that groundwater with the surface water bodies, for the purposes of remedy selection. The factor-of-safety in the risk assessment model run (ENVIRON, 2003) demonstrates that the proposed cap-in-place remedy would offer ample protectiveness even under conditions less favorable than analyzed. A detailed discussion is provided in Exhibit A.

Schnabel Statement—Section 6.4: Regulatory

Several concerns were expressed during the hearings regarding the consolidation of the IRM pile in the summer of 2002. A question was posed asking if the consolidation of the IRM constitutes being "actively managed," thereby classifying the IRM as hazardous waste. Neither DuPont nor DNREC adequately addressed this issue during the hearings or in subsequent responses and communications.

DuPont Comment #63

The consolidation of the IRM pile involved movement of IRM within the original (prior to consolidation) boundaries of the IRM pile and thereby within the boundaries of an area of contamination. In a series of policy and guidance memoranda, the USEPA has clearly indicated that such consolidation does not trigger new RCRA requirements on the material being consolidated. Since the USEPA's directive *Determining When LDRs are Applicable to CERCLA Response Actions* (USEPA, 1989) and the NCP (USEPA, 1990), the USEPA has consistently explained that "placement" does not occur when wastes are consolidated within an area of contamination and thereby that RCRA LDRs do not attach. Furthermore, in his explanation of the AOC concept to RCRA Branch Chiefs and CERCLA Regional Managers in March 1996, the Director of the USEPA Office of Solid Waste distinguished between activities that constitute placement and those that do not constitute placement as follows:

> "In the NCP, EPA stated, 'placement does not occur when waste is consolidated within an AOC [area of contamination], when it is treated in situ, or when it is left in place.' Placement does occur, and additional RCRA requirements may be triggered, when wastes are moved from one AOC to another (e.g., for consolidation) or when waste is actively managed (e.g., treated ex situ) within or outside the AOC and returned to the land."

The consolidation of the IRM pile within its original boundaries clearly did not involve removing IRM from the pile for ex situ treatment and consequently did not constitute "placement" nor "active management." Therefore, the material within the confines of the IRM pile should not be classified as hazardous waste.

Schnabel Statement—Section 6.4: Regulatory

It is Schnabel's opinion that both DuPont and DNREC provided information during the hearings on the complicated issue regarding the relationship and timing between the regulation adoption and key events. However, due to the nature of the hearings, a thorough and coherent explanation was not possible. The poorly selected format of the technical review tended to generate more confusion than assistance. We believe that a summary document should be completed that provides a step by step chronology of the events associated with classifying the IRM along with the underlying regulatory reasoning. This summary should also address the "rehandling" issue (stockpile consolidation).

DuPont Comment #64

DuPont believes that DNREC has an extensive understanding of regulatory events and chronology as it relates to the IRM.

Schnabel Statement—Section 6.4: Regulatory

Observations made during a recent site visit (July 2006) indicated that several surface areas were in need of repair under the current operations and maintenance procedures...We believe that DuPont, in conjunction with DNREC, should provide the public additional and detailed information on this issue.

DuPont Comment #65

The Iron-Rich Staging Area is inspected on a daily and monthly basis. The monthly inspections observe and document site conditions and recommend repairs, etc., as required. The existing storm water and sediment erosion controls are functioning satisfactorily at this time and have been maintained and upgraded as conditions warrant. DuPont has proposed enhancements to these controls to DNREC so that the site can more efficiently transmit storm water flow to the existing outlet structure.

Schnabel Statement—Section 6.6.2: Ground Water and Surface Water

The transcripts from the hearings include questions and comments concerning the lack of a bottom liner for the proposed remedy. One concern was that leachate from the IRM would migrate downward into the ground water and subsequently into the Shellpot Creek and the Delaware River.

DuPont Comment #66

DuPont believes that it has developed an adequate understanding of potential contaminant migration in the groundwater flow regime beneath the site, including the interaction of that groundwater with the surface water bodies, for the purposes of remedy selection. The factor-of-safety in the risk assessment model run (ENVIRON, 2003) demonstrates that the proposed cap-in-place remedy would offer ample protectiveness even under conditions less favorable than analyzed. A detailed discussion is provided in Exhibit A.

Additionally, the cap-in-place remedy will reduce the generation of leachate.

Schnabel Statement—Section 7.1.1.1: Feasibility Study

It is our conclusion that the remedial action objectives (RAO) that were established and used by DuPont in the feasibility, screening, and evaluation of proposed remedies were deficient because proposed concentrations for iron, manganese, and hexachlorobenzene are too high to be protective of human health and the environment. Because of this, the FFS may not have resulted in an appropriate remedy. Additionally, the FFS proposes to only monitor ground water during/after the remedial measures, and has used language which appears to preclude corrective actions that require ground water manipulation, removal and/or treatment.

DuPont Comment #67

These RAOs are based on risk-based evaluations approved by DNREC and are appropriate for the exposure scenarios and site conditions. Because the RAOs are appropriate, the FFS resulted in the selection of the appropriate remedy. For the cap-in-place remedy, DuPont will monitor the groundwater. If groundwater concentrations exceed the proposed RAOs, DuPont will work with DNREC to identify the appropriate remedial actions.

Schnabel Statement—Section 7.1.1.2: Selected Remedy

It is the conclusion of our evaluation that DuPont overstated the design life of the selected remedy (capping system), because it was based on durability and longevity values of the geomembrane base polymer. However, the base polymer durability does not necessarily reflect its ability to perform the intended function once installed.

DuPont Comment #68

Schnabel's conclusion that Peggs (2003) indicates that the maximum operational life of HDPE geomembranes is on the order of 25 years is incorrect. In fact, the Peggs paper *never* makes this statement. Peggs does, however, state that "our practical experience with HDPE geomembranes is limited to about 25 years." Peggs further states that if high quality materials are used in conjunction with good design and quality construction practices, then "an HDPE geomembrane in a MSW [municipal solid waste] landfill should last for about 400 years."

Geomembranes have been used as lining materials (e.g., caps and base liners) for about 30 years. During this time, "adequate performance has been demonstrated" (Peggs, 2003). Because the track record of geomembranes is only a few decades, the question of useful lifetime is often asked. To estimate the durability and aging of geomembranes, accelerated laboratory testing and modeling are used. These methods use elevated temperatures, elevated stresses, and/or aggressive liquids (i.e., leachate) to accelerate the geomembrane aging process. The Geosynthetic Research Institute and others have conducted extensive research on the lifetime prediction of HDPE geomembranes since the 1980s. They have concluded that HDPE geomembranes have extremely long service lifetimes (i.e., hundreds of years when buried) if good quality materials are used and installed properly (i.e., without damage).

Note that the Geosynthetic Research Institute uses the same laboratory testing and modeling procedures as the entire plastics industry for their geomembrane lifetime prediction work. The plastics industry has a longer track record than the geomembrane industry. For example, the cable shielding industry and the plastic gas pipe industry have been using plastic for more than 50 and 40 years, respectively. The Geosynthetic Research Institute uses the same lifetime prediction procedures for geomembranes as these two major industries.

The geosynthetics industry agrees that geomembrane materials will last a long time and that the most critical element in providing a capping system with a long service life is protecting the geomembrane during installation. Succeeding in protecting the geomembrane during installation involves appropriate engineering design, quality construction practices, and construction quality assurance procedures (i.e., inspection and testing during and after installation).

DuPont plans to prepare a quality engineered design, specify quality construction practices, and use construction quality assurance and construction quality control during the implementation of the DNREC-approved remedy.

Schnabel Statement—Section 7.1.1.2: Selected Remedy

…Regarding DuPont's other leading remedy, source removal and disposal, we have concluded that it was not thoroughly evaluated, particularly for the use of rail transportation options (in lieu of trucking) which would significantly reduce the cost and the apparent risk.

DuPont Comment #69

From a risk perspective, the transportation risk of rail versus truck transport is not significantly different (see Exhibit E), which further supports the current cap-in-place remedy. The duration of the source removal and disposal alternative, as stated previously in these comments, is on the order of several years (versus the originally estimated 12 months).

Schnabel Statement—Section 7.1.2: Risk Assessment

To the extent that site characterization data and conceptualization (of IRM and DM) serves as the foundation of the risk assessment, the human health and ecological risk assessments for the site have significant shortcomings. Our evaluation indicates that related shortcomings and inconsistencies include representation of source/exposure point concentrations, conceptual assumptions, and input parameters used in fate and transport modeling analyses.

DuPont Comment #70

DuPont believes that the site characterization is appropriate and supports the cap-in-place alternative. Further, the risk assessment (that was performed per DNREC screening assessment requirements as well as the more site-specific evaluations performed by DuPont and ENVIRON) make conservative assumptions that result in the overestimation (rather than underestimation) of potential risk. DuPont believes that the evaluations provided thus far support the use of a cap-in-place remedy as protective of human health and the environment.

Schnabel Statement—Section 7.1.2: Risk Assessment

Moreover, the human health risk assessment (HHRA) has ignored a potentially critical exposure scenario related to offsite downwind receptors (including potential sensitive receptors). Similarly, the ecological risk assessment (ERA) appears to have inappropriately excluded hazards related to potential direct exposure to COC by wildlife (avian and terrestrial species were observed foraging in the IRM areas during our site reconnaissance visit), and the observed vegetation on the IRM pile serving as a potential food source and habitat for such wildlife.

Additionally, the off-site ecological exposure point concentrations and the subsequent ecological risk to aquatic organisms and human receptors vary significantly with COC concentrations in the IRM and dredged material, the vertical permeability of the IRM, and the assumed hydraulic conductivity of the DM. These types of data should be collected from within the footprint of the IRM pile and its immediate vicinity for effective off-site ecological risk characterization, and the ERA should be revised accordingly to reflect new data. Further, cumulative human health carcinogenic risk calculated by DNREC staff as a result of consumption of impacted fish using dioxin and dioxin-like compound analytical fish tissue data collected from Shellpot Creek is approximately 10 to 5,000 times higher than that calculated by DuPont for this exposure scenario. Unless high dioxin levels are established in sediments in and around the vicinity of the site, the excess human health risk for this exposure scenario should be recalculated by DuPont.

DuPont Comment #71

DuPont disagrees that wind-blown dust was not considered in the human health risk assessment. As Appendix A correctly notes, under conditions at the time of the evaluation as well as the planned remedy, exposure by inhalation of COPCs in wind-blown dust is minimal for on-site workers. By extrapolation, the pathway would be incomplete for off-site receptors of which the adjacent water bodies are the most relevant.

While assessment of this pathway is not a DNREC requirement, the pathway was a focus of the potential historic release evaluation as well as the remedy selection evaluation. Based on a meteorological assessment, the appropriate receptors are the adjacent water bodies. The results of the historic release evaluation, which focused on dioxins and PCBs as the most critical constituents, concluded the following:

- Estimated concentrations in the adjacent water bodies resulting from the uncovered pile were not above the ambient water quality criteria.
- Cumulative risks were calculated to be approximately an order of magnitude below *de minimus* level (i.e., 2.0×10^{-7} vs. 1.0×10^{-6} risk) for the reasonable worst case and well within the acceptable risk range of 10^{-4} to 10^{-6}. For the maximum worst case, cumulative risks were calculated to be only marginally above the *de minimus* level (i.e., 1.8×10^{-6} vs. 1.0×10^{-6}).

In addition, an assessment of risk to a hypothetical resident at the fence line was performed to evaluate remedy implementation of the two options. In both cases, risks were higher for excavation versus capping. The cancer risk was below 10^{-6} for both, and the hazard index was less than 1 for noncancer effects under the capping option and 21 under the excavation option.

Consistent with standard risk assessment protocols, a site conceptual model was used to define *all relevant* COPCs, exposure pathways, and receptors. At the time when the RI/RA report was submitted, the IRM did not support vegetation. DuPont presumed that the remedy would be implemented in a relatively short period of time. Voluntary vegetative growth has occurred within the last year. DuPont is currently working with DNREC on an enhanced storm water and sediment erosion control plan, which will include an appropriate temporary cover for the pile. As the Schnabel Report correctly notes, the IRM storage area is not a "robust wildlife habitat." DuPont agrees with Schnabel's conclusion earlier in Section 2.5.1 that "…the completion of the proposed remedy will reduce/eliminate the direct contact route, and therefore the data are sufficient" and reiterated in Section 2.6.4: "this would not be an issue under either remediation option."

On the issue that Schnabel report has designated as ERA, it should be noted that this is an incorrect designation and is inconsistent with how ecological risks were evaluated. For clarification, DNREC requirements for evaluation under the VCP Agreement scope of work include an option for human health and one for ecology (DNREC, 2002). The human health evaluation as attributed above met all DNREC requirements. For ecology, DNREC requires a similar process of comparison to criteria and only those constituents that fail these criteria are carried forward. DuPont went further than required and performed additional risk evaluations (e.g., DuPont, 2003 and ENVIRON, 2003). These efforts evaluated both human and ecological receptors as quoted by Schnabel above. The Schnabel Report shows a lack of understanding of ecological risk assessments (and human health risk assessments) by consistently referring to potential human exposure pathways (e.g., ingestion of fish, recreational use) as part of an ecological risk assessment.

There is a significant background level of dioxins that can originate from a variety of natural and anthropogenic sources. Sediment data collected by DuPont and fish tissue data collected by DNREC suggest that DuPont is not a significant contributor of dioxins to the creek. The total DuPont contribution represents less than 0.1% of the total dioxin/furan toxic equivalents present in the fish tissue. This has been communicated to DNREC (DuPont, 2002).

The conclusions of the Shellpot Creek watershed screening assessment are as follows:

- ❑ IRM has a distinct distribution pattern of both PCBs and dioxin/furan congeners.
- ❑ The principal sources of both PCBs and dioxins exist in Shellpot Creek above Hay Road.
- ❑ The data suggest that IRM may contribute to the nonachlorobiphenyl and decachlorobiphenyl concentrations in lower Shellpot Creek. These homologs make up less than 1% of the total PCB content found in the fish tissue from Shellpot Creek.
- ❑ The data suggest that IRM may contribute to the OCDF concentrations in lower Shellpot Creek. These congeners make up less than 0.01% of the total dioxin/furan TEQ found in the fish tissue from Shellpot Creek.

DuPont believes that the site characterization is adequate for the purposes of the risk assessment. Further, the risk assessment (that was performed per DNREC screening assessment requirements as well as the more site-specific evaluations performed by DuPont and ENVIRON) make conservative assumptions that result in the overestimation (rather than underestimation) of potential risk. DuPont believes that the evaluations provided thus far support the use of a cap-in-place remedy as protective of human health and the environment.

Schnabel Statement—Section 7.1.3.1: Dredged Material

It is the conclusion of our evaluation that the dredged material upon which the IRM is currently stored, and upon which it will be permanently stored in the proposed remedy, has not been sufficiently characterized.

DuPont Comment #72

DuPont believes that it has developed an adequate understanding of the site subsurface for the purposes of remedy selection. Extensive geotechnical investigations have been conducted at the site, including multiple studies in the early 1970s, Cell 2 investigations (1977), Cell 3 investigations (1978 through 1979), Cell 4 investigation (1990), landfill closure investigation (1992), and the pre-design investigation (2000). Exhibit A illustrates the numerous soil borings, test pits, wells, and piezometers that have been employed to understand the site subsurface. DuPont is aware that heterogeneities may influence the bulk permeability of a unit. However, sand beds or laminations within the dredged materials were thin and not laterally correlative, indicating they are likely discontinuous lenses rather than extensive flow pathways.

As Schnabel states, permeability data are available for several locations west of the IRM storage pile at various depths. Boring logs are also available for locations across the site, both in the areas where the permeability data were collected and under the IRM pile (see Exhibit A). The logs of the 14 borings within, or on the margin of, the footprint of the IRM pile indicate that the materials beneath the pile are comparable to those used for the permeability analyses. The hydraulic conductivity value of 4.6 x 10^{-2} cm/sec cited by Schnabel was obtained from the Shallow Sand unit in the western portion of the site, not from the dredged materials that underlie the IRM storage area. The highest vertical hydraulic conductivity measured on any of the dredged materials at the site was 1.1 x 10^{-5} cm/sec.

DuPont, under the guidance of DNREC, chemically characterized the DM formerly covered by IRM (DM-1 through DM-14). The characterization was adequate to allow risk assessment modeling under conservative assumptions and is therefore sufficient for remedy selection.

Schnabel Statement—Section 7.1.3.2: Ground Water

It is the conclusion of our evaluation that the ground water underlying the IRM has not been fully characterized, and ground water monitoring locations are not positioned to effectively: (1) establish the existing impacts of the stockpiled IRM on the ground water quality, and (2) monitor the future impact of the proposed remedy. This includes the lack of ground water data within the footprint of the IRM, and in at least one key downgradient location near the point of discharge to the Delaware River. Additionally, semi volatile organic compounds such as hexachlorobenzene and hexachlorobutadiene reported in IRM and DM samples, which are potential COC, have not been analyzed in past and current ground water monitoring events. Because of this, ground water has not been sufficiently characterized to effectively perform a FFS and the associated risk assessment.

DuPont Comment #73

DuPont believes that the groundwater has been sufficiently characterized to support the proposed remedy. Our conclusion is based on historical sampling and analysis and groundwater modeling performed at the site. DuPont also acknowledges that future monitoring will need to occur in support of the remedy.

With respect to historical groundwater sampling, groundwater wells (MW-36A, MW-42, MW-46R, MW-47R and MW-48) of the First Aquifer are sampled on a semiannual basis at

Cherry Island as part of the postclosure care permit for Cells 1 through 3. Exhibit G shows the location of the monitoring wells at Cherry Island. Analytical parameters include ammonia, chlorides, metals (arsenic, cadmium, chromium, copper, iron, lead, and selenium), total dissolved solids, and total organic carbon. Field parameters include dissolved oxygen, oxidation-reduction potential, pH, specific conductance, and turbidity.

Additional groundwater sampling and analysis occurred on March 15, 2005. Wells MW-34A, MW-36A, MW-37, and MW-46R (see Exhibit G) were sampled at DNREC's request for TAL metals, cyanide, TCL organics (including the SVOCs HCB and hexachlorobutadiene), pesticide/PCBs, and dioxin/furans. These data were submitted to DNREC on April 5, 2005, and indicated that no HCB or hxachlorobutadiene was detected in any of the tested wells.

Leachate and groundwater flow modeling was performed (ENVIRON, 2003). The leachate model performed used was the USEPA HELP (USEPA, 1994). The groundwater flow model used was Oak Ridge National Laboratories' AT123D model (USEPA, 1989). The modeling results demonstrated that the COPCs do not pose any appreciable risks through leaching and transport to nearby surface water bodies.

DuPont believes that the well cluster between the IRM and Shellpot Creek (i.e., MW-33R, MW-34A, and MW-46) and the well cluster between the IRM and the Delaware River (i.e., MW-35, MW-36A, and MW-37) are positioned to effectively detect any potential release from the IRM toward the Shellpot Creek and the Delaware River, respectively. Please see Exhibit G shows the well locations with respect the IRM and the surface water bodies.

Schnabel Statement—Section 7.1.3.3: IRM

The evaluation of the IRM in relation to the proposed remedy indicates that the IRM has not been sufficiently characterized to allow for the effective risk assessment of the proposed remedy. The lack of characterization includes the lack of site-specific hydraulic conductivities established for the IRM and the significance of hexachlorobenzene, including its potential presence as a dense non-aqueous liquid (DNAPL) occurring within the IRM.

DuPont Comment #74

The hydraulic conductivity selected for the IRM for use in ENVIRON's HELP model (Tables 5e and 5f; ENVIRON, 2003) shows a generic soil texture number 12. However, in the actual computer modeling runs, a soil texture number 8 was used. This "inorganic silts and very fine sands" (ML) type soil texture and its associated hydraulic conductivity value (3.7×10^{-4} cm/sec) is representative of the IRM based on two hydraulic conductivity tests conducted on IRM during the application process for a U.S. Patent for its use in landfill capping systems in 1992. This 1992 testing report is provided as Exhibit H. In fact, the two tested hydraulic conductivity values (at 10^{-5} cm/sec) are lower than the one used in the modeling. That is, a more conservative approach was used.

Because the aqueous solubility is low and the melting point for HCB is high, HCB would be expected to form a solid phase at concentrations above the soil saturation concentration, rather than a NAPL. As referenced in earlier comments, DuPont does not expect that HCB would exist as a liquid under IRM conditions.

Schnabel Statement—Section 7.2: Recommendations – IRM

We believe that up to five representative samples should be collected of the IRM currently stored from within the footprint of the proposed remedy located in the eastern portion of the site…Samples should be collected from appropriately spaced borings with the proposed locations approved by DNREC.

DuPont Comment #75

Samples of the IRM were collected from the waste stream just prior to transport and emplacement at the Hay Road site. Because this sampling occurred at various times throughout the disposal history and because of the proximity of the plant to the site (i.e., minimal transport), DuPont believes that the IRM is adequately characterized.

Schnabel Statement—Section 7.2: Recommendations – Dredged Material

In conjunction with the advancement of the recommended borings, we believe that representative samples of the dredged material be collected at 2.5-ft intervals beneath the stored IRM. Additionally, samples of dredged material in the southeast corner of the site should be collected at 2.5-ft intervals. A minimum of 10 ft of dredged material should be sampled at each location.

DuPont Comment #76

DuPont believes that it has developed an adequate understanding of the site subsurface for the purposes of remedy selection. Extensive geotechnical investigations have been conducted at the site, including multiple studies in the early 1970s, Cell 2 investigations (1977), Cell 3 investigations (1978 through 1979), Cell 4 investigation (1990), landfill closure investigation (1992), and the pre-design investigation (2000). Exhibit A illustrates the numerous soil borings, test pits, wells, and piezometers that have been employed to understand the site subsurface. DuPont is aware that heterogeneities may influence the bulk permeability of a unit. However, sand beds or laminations within the dredged materials were thin and not laterally correlative, indicating they are likely discontinuous lenses rather than extensive flow pathways.

As Schnabel states, permeability data are available for several locations west of the IRM storage pile at various depths. Boring logs are also available for locations across the site, both in the areas where the permeability data were collected and under the IRM pile (see Exhibit A). The logs of the 14 borings within or on the margin of the footprint of the IRM pile indicate that the materials beneath the pile are comparable to those used for the permeability analyses. The hydraulic conductivity value of 4.6×10^{-2} cm/sec cited by Schnabel was obtained from the Shallow Sand unit in the western portion of the site, not from the DM that underlies the IRM storage area. The highest vertical hydraulic conductivity measured on any of the DM at the site was 1.1×10^{-5} cm/sec.

DuPont, under the guidance of DNREC, chemically characterized the DM formerly covered by IRM (DM-1 through DM-14). The characterization was adequate to allow risk assessment modeling under conservative assumptions and is therefore sufficient for remedy selection.

Schnabel Statement—Section 7.2: Recommendations – Ground Water

To establish the quality of the ground water within the footprint of the proposed remedy and downgradient of the IRM storage pile, a ground water well should be installed and sampled…Hydraulic conductivity data should be collected from selected horizons in conjunction with the installation of this well.

DuPont Comment #77

The long-term effectiveness of the proposed remedy will be verified through a groundwater monitoring program that will be addressed in a postclosure monitoring plan.

Schnabel Statement—Section 7.2: Recommendations – Feasibility Study

Upon completion of the recommended data gathering activities, the FFS should be revised to incorporate the new data and the feasibility of each of the remedies in the screening process should be re-evaluated to determine their rankings and appropriateness.

DuPont Comment #78

DuPont believes that the site has been adequately characterized to provide the data necessary to complete the FFS and select the proposed remedy.

Schnabel Statement—Section 7.2: Recommendations – Risk Assessment

Upon completion of the recommended data gathering activities and the incorporation of the additional testing and analytical results into the revised FFS, we are recommending that the risk assessments of the selected remedies be revised to reflect the inclusion of the new data.

DuPont Comment #79

DuPont believes that the site has been adequately characterized to provide the data necessary to complete the risk assessment and select the proposed remedy.

EXHIBIT A

SUBSURFACE CHARACTERIZATION UNDER THE IRM STORAGE PILE

Exhibit A
Subsurface Characterization under the IRM Storage Pile

Note: In keeping with Schnabel's usage, the terms "permeability" and "hydraulic conductivity" are used interchangeably herein to refer to "hydraulic conductivity" or "coefficient of permeability" of a material, in units of length/time (cm/s).

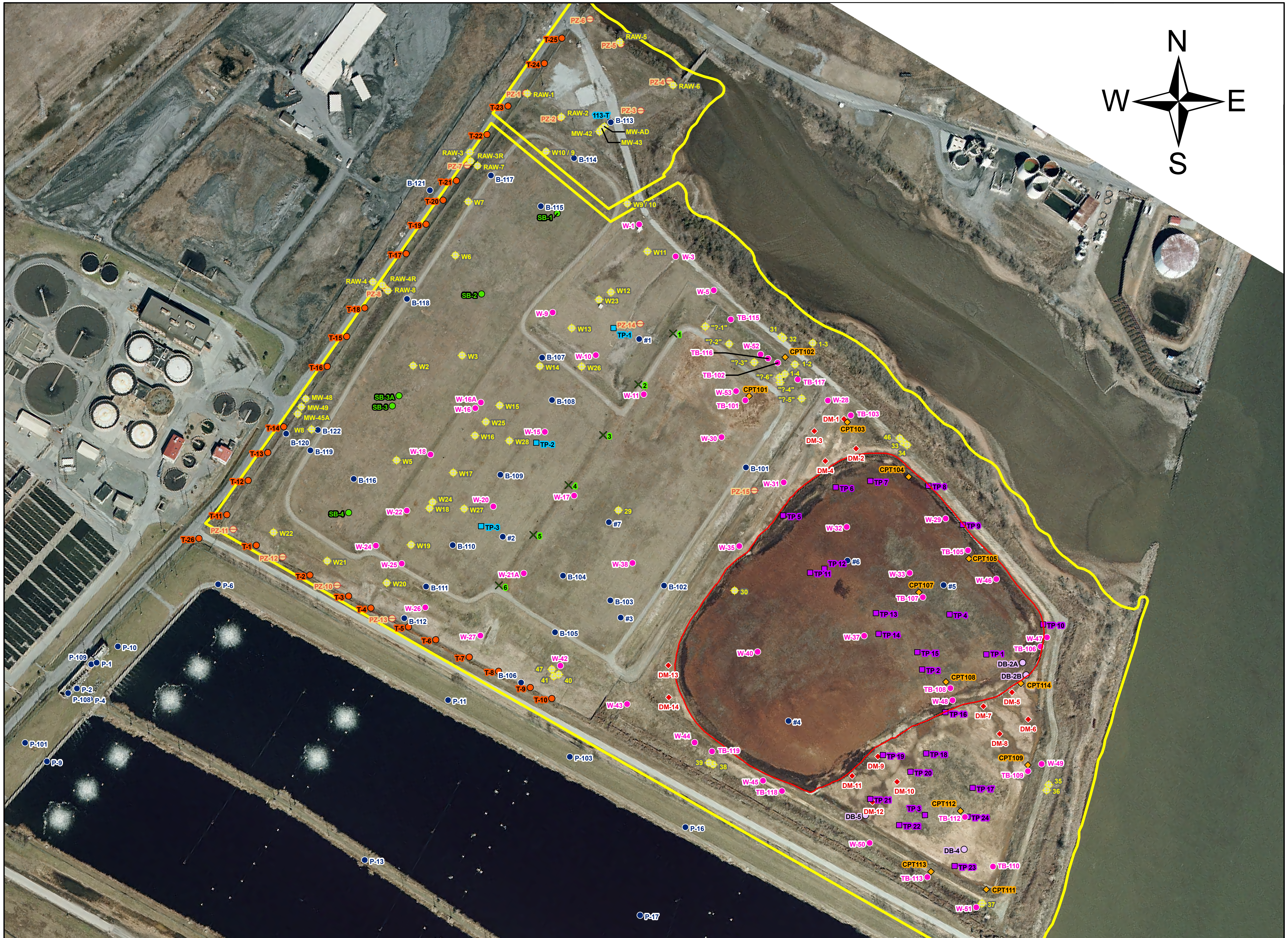
Extensive geotechnical investigations have been conducted at the site, including multiple studies in the early 1970s, Cell 2 investigations (1977), Cell 3 investigations (1978 through 1979), Cell 4 investigation (1990), landfill closure investigation (1992), and the pre-design investigation (2000). This exhibit illustrates the numerous soil borings, test pits, wells, and piezometers that have been employed to understand the site subsurface. DuPont is aware that heterogeneities may influence the bulk permeability of a unit.

Logs are available for 14 previous (historical) borings located within or on the margin of the footprint of the IRM pile [DB-2A, TB-30 (well 30), TB-105, TB-106, TB-107, TB-108, W-29, W-32, W-33, W-37, W-40, W-46, W-47, and W-48]. The logs for all of these borings (see attached) indicate silty-clay/clayey-silt from the surface to a depth of 13 to 22 feet bgs. Although some of these logs note the presence of sand lenses within the DM, in nearly all cases, the depth to the shallowest sand lens is greater than 10 feet, and there is no indication that any sand lenses are continuous or interconnected.

Vertical hydraulic conductivity measurements from Shelby tube samples of the silty-clay/ clayey-silt material yielded an arithmetic mean of 3.4 x 10^{-6} cm/sec (geometric mean of 1.4 x 10^{-6} cm/sec). For groundwater flow calculations and modeling, DuPont assumed an anisotropy ratio of 10:1 (horizontal:vertical), which is typical for a layered unconsolidated material (Freeze and Cherry, 1979). This assumption is confirmed by horizontal hydraulic conductivity measurements obtained by slug testing (arithmetic mean of 2.2 x 10^{-5} cm/sec; geometric mean of 2.0 x 10^{-5} cm/sec). The highest vertical hydraulic conductivity value of the silt/clay "dredged material" was 1.1 x 10^{-5} cm/sec from PZ-14. The hydraulic conductivity value of 4.6 x 10^{-2} cm/sec cited by Schnabel was from the "Shallow Sand" unit in the western portion of the site, *not in the dredged materials that underlie the IRM storage area*. This unit is correlated with the unit referred to previously (Woodward-Clyde Consultants, 1977, 1979) as "Unit 3."

ENVIRON acknowledged the importance of conductivity, stating "horizontal hydraulic conductivity in the saturated zone is a key parameter in the groundwater modeling." However, given the conservative assumptions used in the modeling, variations in hydraulic conductivity over the observed range of 10^{-7} to 10^{-5} cm/sec would not change the conclusions of the risk assessment.

For confirmation, the technical team at ENVIRON was consulted regarding the modeling of chemical transport from the IRM stockpile to the Delaware River and Shellpot Creek (presented in the risk assessment). DuPont understands that the expert opinion of ENVIRON's modeling team is that even if the horizontal hydraulic conductivity of the DM underlying the IRM pile were assumed to be 1.1. x 10^{-4} cm/sec, an order of magnitude higher than the highest result obtained from Shelby tube analyses of the DM, *the overall conclusion of the risk assessment would not change*. ENVIRON confirmed, via e-mail on February 22, 2007: “This conclusion was that essentially unlimited concentrations of each of the chemicals of potential concern could be present in the IRM staging pile and still not result in an exceedance of risk-based surface water quality criteria.”



Legend

- Monitoring Well
- Pre-Slurry Wall Boring
- Soil Boring
- Shallow Boring (1979)
- Deep Boring (1979)
- Test Boring
- Piezometer
- Test Pit
- Test Pit (2001)
- Cone Penetrometer Test
- Dredged Material Sample
- Unknown
- Iron Rich Material Footprint
- Site Outline

Notes:
All location points are approximate, digitized in GIS from scanned images or CAD drawings georeferenced to DE State Plane NAD83 (ft) coordinate system or manually digitized using landmarks on hardcopy maps.

Iron Rich Material footprint digitized in GIS from georeferenced 2006 aerial (shown). Aerial source: Delaware Solid Waste Authority.

Site Outline source: New Castle County Tax Parcels, downloaded from the Delaware DataMIL (datamil.delaware.gov).

0 100 200 400
Feet
1:3,600

DUPONT

CORPORATE REMEDIATION GROUP

An Alliance between DuPont and URS Diamond

BMP 19
Barley Mill Plaza
Wilmington, DE 19805

Exhibit A
Subsurface Investigation Locations

DuPont Hay Road Facility
Edgemoor, DE

Created:	DuPont Project Number:
CAA	8795
Date: 03/01/2007	URSD Project Number: 18984767.20062
Rev Number: 0: Date: 03/01/2007	Figure Number: Exhibit A
File Name: SubSfc_Invest_Locs.mxd	

LOG of BORING No. DB-2

DATE 3-15-79 SURFACE ELEV. 22.9 LOCATION See Plate 1

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	3	Very soft gray clayey silt, trace mica with vegetation					
	1/12						
	1/12						
5	WOH						
10	2		9.9				
15	6	Medium dense gray silty fine sand, trace mica					
20	6		-0.1				
25	42	Very dense silty, coarse to fine sandy fine gravel, little clay	-6.1				
30	10	Firm to stiff clayey silt with thin layers of medium to fine sand, trace mica		54.4	73	36	
35	5		-13.6	60.5			
		* Observation well installed with 30 inch screened well-point at 24.8 feet					

COMPLETION DEPTH 36.5 feet Water Depth 9.7 feet * Date 3-23-79

10.7 feet 4-12-79

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

LOG of BORING No. DB-2A

DATE 3-17-79 **SURFACE ELEV.** 20.0 **LOCATION** See Plate 1

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
30		Straight auger boring to 37.5 feet, refer to DB-2 for soils encountered 0 to 36.5 feet	-17.5				
	P	Stiff gray clayey silt, trace coarse sand to fine gravel					
40	14		-23.0	46.5	54	34	
45	4	Soft to firm silty clay with thin layers of fine sand, trace mica		65.4			
	FV						
50	6			57.4	76	34	
55	3			62.9			
	P			40.7			T
				47.2	80	33	
60	4			53.0			W
			-42.0	64.6	53	29	
	FV	Firm gray silty clay with vegetation remnants and occasional trace of fine gravel					
65	P			62.1[1]	79	33	T
	5			57.9			W
	FV						
70	P						
	FV						
75	P			64.8[1]	74	36	

COMPLETION DEPTH 106.5 feet Water Depth 1.3 feet Date 3-22-79

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER 1- Avg. water content

DATE

DEPTH, FEET	SAMPLING RESISTANCE
75	P
	5
	FV
80	5
85	
	5
90	FV
95	5
100	16
105	23
110	

COMPLETION

SAMPLER: 2"

ate 1

LIMIT, %	OTHER TESTS
4	
4	
	T
3	W
9	
3	T
	W
6	

79

LOG of BORING No. DB-2A

DATE 3-17-79 **SURFACE ELEV.** 20.0 **LOCATION** See Plate 1

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
75	P	Firm gray silty clay with vegetation remnants and occasional trace of fine gravel		64.8	74	36	T W
	5						
	FV						
80	5			83.1	72	34	
85							
	5			48.9	56	25	
90	FV						
95			-75	62.8			
	5	Stiff tan silty clay	-75.2	21.2			
		Firm gray silty clay with thin layers of coarse to fine sand and fine gravel	-79.5				
100	16	Medium dense gray silty medium to fine sand	-83.5	15.3			M
105	23	Medium dense red-brown clayey medium to fine sand	-86.5	18.6			
110							

Undisturbed piston samples obtained from off-set boring at following depths:

45.5 to 48.0 feet
68.0 to 70.5 feet
85.0 to 87.5 feet

DB-2A was offset 39 feet north of DB-2 augered to 35 feet without sampling and testing before continuing further

COMPLETION DEPTH 106.5 feet **Water Depth** 1.3 feet **Date** 3-22-79

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

WALTON CORPORATION
Drilling Contractor
P. O. BOX 1097, NEWARK, DELAWARE 19711

BORING LOG

NAME DuPont Company Cherry Island PROJECT NO.
Wilmington, Del. SUPERVISOR L. Labonne

BORING NO. 30 & 30A | DRILLER B. Erickson | DATE 5-27/31-74
WEATHER (1000' from gate) | SURFACE ELEVATION | DATUM

Sample No.	Sample Depth - Feet From	Sample Depth - Feet To	Depth Strata Feet From	Depth Strata Feet To	Driller's Description of Materials	*Blows A		
			0	10.5	Gray Silt & Clay w/Layers of			
					decomposed vegetation			
			10.5	11.0	Hard Decomposed Vegetation &			
					Wood (Refusal)			
					Offset hole 13.0' east, towards			
					river.			
					Boring # 30A			
			0	19.0	Gray Silt & Clay w/layers of			
					decomposed vegetation.			
			19.0	29.0	F/M Brn. Sand, Gray Silt & Clay			
					w/layers of wood			
			29.0	43.0	Gray Clay (Soft)			
			43.0	44.5	Gray Clay, Tr. of Sand			
			44.5	51.0	Brn. Very Coarse Sand			
					Total drilled depth 51.0'			
					Screen set 46.0 - 51.0			
					W/L @ completion 46.0			

BLOWS ON CASING B
0- 1
1- 2
2- 3
3- 4
4- 5
5- 6
6- 7
7- 8
8- 9
9-10
10-11
11-12
12-13
13-14
14-15
15-16
16-17
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19-20
20-21
21-22
22-23
23-24
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27-28
28-29
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42-43
43-44
44-45
45-46
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48-49
49-50
50-51
51-52
52-53
53-54
54-55
55-56
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57-58
58-59
59-60
60-61

1

*A Number of blows of 140 lb. hammer dropped 30 in. required to drive 2 in. split-spoon sampler for each of three 6 in. increments.

* B Number of blows of 300 lb. hammer dropped 18 in. required to drive .... in. casing 12 inches.

REMARKS: # 30 Refusal @ 11.0 w/6" Roller Bit

GROUND WATER

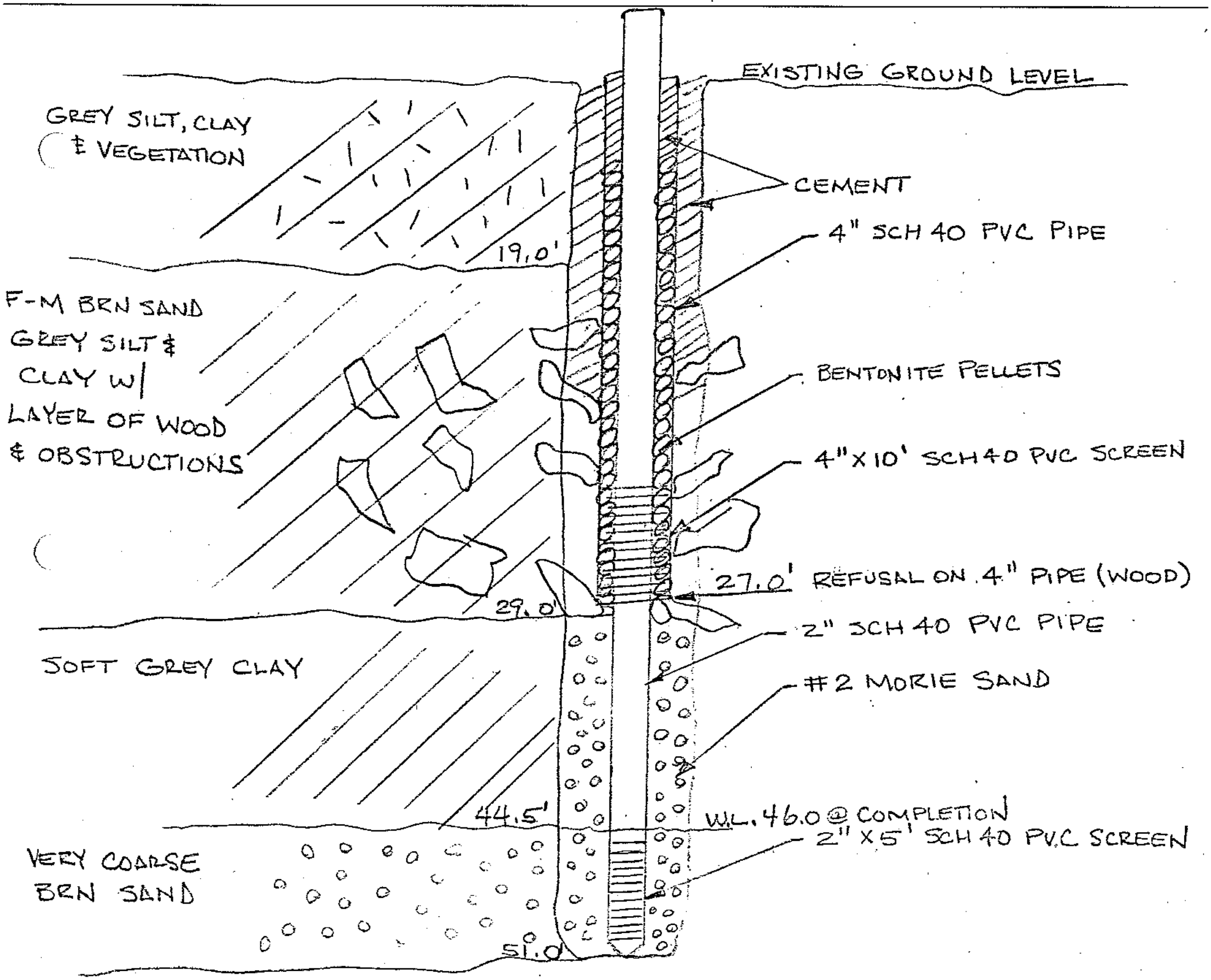
WALTON CORPORATION

Drilling Contractor
PAPER MILL ROAD – P. O. BOX 1097
NEWARK, DELAWARE 19711

Phone: (302) 737-6480

E.I. DUPONT DENEMOURS & COMPANY
EDGEMOOR, DELAWARE
CHERRY ISLAND SITE

WELL NO. 30A
(1000' FROM GATE)



LOG of BORING No. TB-103 (cont'd)

Sheet 3 of 3

DATE 4/5-8/88 SURFACE ELEVATION 24.1 LOCATION See Figure 2

DEPTH, ft.	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
90	Ps	As above	-66.9				
	Vs	Medium dense dark gray interbedded coarse to fine sand and gravel with fine brown silty clay (SW/CL)		33.8			
95	26			27.5			
100	19			26.8			
105	12			18.1			
			-83.9				
110	24	Hard red-brown coarse to fine sandy clay (CL)	-87.4	18.6			
115		* Drilled with mud, no water levels available					

Completion Depth 111.5 Feet Water Depth * Feet Date 4/9/88

Project Name DuPont - Cherry Island - Cell #3 Project Number 88C2042C

Woodward-Clyde Consultants

LOG of BORING No. TB-105

1 of 3

DATE 4/9-14/88 SURFACE ELEVATION 23.1 LOCATION See Plate 2

DEPTH, ft.	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER
0							
	4	Firm dark gray clayey silt with medium to fine sand lenses, traces of vegetation matter, micaceous (MH)		45.6			
5	Ps			68.3	76	42	Pp1. TvO
	Vs						
10	Ps			102.9	98	42	G,H Tx
	Vs						
15	Ps			28.1			
	Vs						
20	Ps			24.7			
			+1.1				
25	19	Medium dense dark gray silty coarse to fine sand and gravel (SW/SM)		10.1			H
30	17			18.3			
			-10.9				
35	Ps	Firm dark gray clayey silt/organic clay, trace mica (MH/OH)		44.4			Pp2 TvO
	Vs						
40	Ps			59.1			Pp1 TvO G,H Tx
45	Ps	Continued on Sheet 2 of 3					

Completion Depth 106.5 Feet Water Depth * Feet Date 4/15/88

Project Name DuPont - Cherry Island - Cell #4 Project Number 88C20428

Woodward-Clyde Consultants

WCC-RP1

LOG of BORING No. TB-105 (cont'd)

DATE 4/9-14/88 SURFACE ELEVATION 23.1 LOCATION See Plate 2

DEPTH, ft.	SAMPLES / SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45	Ps	As above	-22.4	20.7			
		Firm gray coarse to fine sandy, gravelly silty clay (CL/CC)	-24.4				
50		Firm gray silty clay (CH)	-26.9		67	37	G,M Tx
	Ps	Firm dark gray silty medium to fine sand (SM)	-27.9	62.2	87	44	Pp1.5 Tv0.6
	Vs						
55	Ps	Firm dark gray organic silty clay/ clayey silt, trace vegetative material (CH/OH)		60.5			Pp1.8 Tv0.3
	Vs						
60	Ps			62.2	89	43	Pp1.8 Tv0.5 G,Tx M
	Vs						
65	Ps			59.1	87	29	Pp1.3 Tv0.5
	Vs						
70	Ps			63.9	77	37	Pp1.5 Tv0.5 G,Tx M
	Vs						
75	Ps			69.4			Pp1.8 Tv0.5
	Vs						
80			-56.9				
	Ps	trace fine gravel	-58.9	78.7	95	57	Pp1.8 Tv0.4 G,Tx M
	Vs						
85	Ps			53.9			Pp1.5 Tv0.5
	Vs						
90	Ps	Continued on Sheet 3 of 3					

Completion Depth 106.5 Feet Water Depth * Feet Date 4/15/88
Project Name DuPont - Cherry Island - Cell #4 Project Number 88C2042B

Woodward-Clyde Consultants

LOG of BORING No. TB-105 (cont'd)

DATE 4/9-14/88 SURFACE ELEVATION 23.1 LOCATION See Plate 2

DEPTH, ft.	SAMPLES / SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
90	Ps	As above	-67.4				
		Medium dense brown-gray coarse to fine sand and gravel (SW)					
95	25			9.1			M
			-75.9				
100	71	Hard red-brown-green-gray fine sandy clay to sandy clayey silt (CL/ML)		26.3	40	31	M
105	75		-83.4				
110		* Drilled with mud rotary, no water levels obtained					

Completion Depth 106.5 Feet Water Depth * Feet Date 4/15/88
Project Name DuPont - Cherry Island - Cell #4 Project Number 88C2042B

Woodward-Clyde Consultants

WCC-BP1

LOG of BORING No. TB-106

DATE 4/20-25/88 SURFACE ELEVATION 22.9 LOCATION See Plate 2

DEPTH, ft.	SAMPLES / SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0		Firm mottled dark brown and orange silty clay with organic inclusions (CH/OH)					
	6			58.4			
5			17.9				
	4	Firm dark gray organic clayey silt/silty clay with trace fine sand and gravel (OH/CH)		56.0			
	Ps						
10	Ps			78.0	115 101	57 53	G,M Tx
	Vs						
15	Ps			67.5			
	Vs						
20	Ps		+1.4	50.8 42.2 30.6	54	35	G,M C,Tx
		Firm dark gray organic silty clay, some medium to fine sand and fine to coarse gravel becoming medium dense dark gray to black silty fine to coarse sand with some fine to coarse gravel, silty clay lenses (OH/SM)					
25	15			23.2			
30	48			13.6			
35	12		-13.1	36.0			
		Soft to firm dark gray organic clayey silt to silty clay with trace gravel, silty fine sand lenses (OH)					
40	Ps			61.5	79	42	G,M Tx
	Vs						
45		Continued on Sheet 2 of 3					

Completion Depth 116.5 Feet Water Depth * Feet Date 4/26/88

Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

HCC-RP1

LOG of BORING No. TB-106

DATE 4/20-25/88 SURFACE ELEVATION 22.9 LOCATION See Plate 2

DEPTH, ft.	SAMPLES / SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45	Ps	Firm dark gray organic clayey silt to silty clay with trace sand, mica (OH)		78.3			
	Vs						
50	Ps			54.1 66.5 42.4	59	33	C,I C,T
	Vs						
55	Ps		-32.6	52.6	88 68	45 36	C,
		Trace fine sand	-34.6				
	Vs						
60	Ps			65.1	81	37	
	Vs						
65	Ps			54.1			
	Vs						
70	Ps		-48.1	75.2	75	39	C, Tx
		Little organic inclusions	-50.6				
	Vs						
75	Ps			62.4			
	Vs						
80	Ps			62.5	66	39	C,I Tx
	Vs						
85	Ps			48.0			
	Vs						
90		Continued on Sheet 3 of 3					

Completion Depth 116.5 Feet Water Depth * Feet Date 4/26/88

Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

LOG of BORING No. TB-106

DATE 4/20-25/88 SURFACE ELEVATION 22.9 LOCATION See Plate 2

DEPTH, ft.	SAMPLES / SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
90	Ps	Firm dark gray organic clayey silt (OH)	-68.1	28.7			
		Dark gray silt and medium to coarse sand (SM)	-71.1				
95	Ps	Soft to firm dark organic clayey silt with trace coarse sand, trace mica (OH)		59.1	66 78	39 46	G,H Tx
	Vs		-76.1				
100	9	Loose to medium dense multicolored (brown, red-brown, gray, dark gray) fine to coarse sand, some silt, trace gravel, weathered rock fragments towards bottom (SW)		38.5			
105	22						
110	16			18.7			
115	31		-93.6				

* Drilled with mud, no water levels available

Completion Depth 116.5 Feet Water Depth * Feet Date 4/26/88
Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

LOG of BORING No. TB-107

DATE 4/14/-19/88 SURFACE ELEVATION 22.3 LOCATION See Plate 2

DEPTH, ft.	SAMPLES / SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0							
	3	Soft to firm dark gray organic silty clay (OH)		68.3			
5	Ps			61.9			
	Vs						
10	Ps			71.6	77 114	50 56	G,I Tx
	Vs		7.3				
15	Ps	Firm dark gray organic clayey silt (OH)		72.6			C,T C,M
			4.3				
	Vs	Loose dark gray silty medium to fine sand, little coarse sand (SM)	1.8				
20	3	Soft to firm dark gray organic silty clay (OH)	-2.7	35.3			
25	7	Loose to medium dense black silty coarse to fine sand and coarse to fine gravel (SM/SW)	-6.7	20.6			H
30	Ps	Firm to stiff dark gray organic clayey silt to silty clay, traces of fine to medium sand and gravel (OH)		67.8			
	Vs		-12.7				
35	Ps	Trace fine gravel	-14.7	48.9	56	34	C,C H,T
	Vs						
40	Ps			53.7			
	Vs		-22.7				
45							

Continued on Sheet 2 of 3

Completion Depth 106.5 Feet Water Depth * Feet Date 4/20/88
Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

LOG of BORING No. TB-107

DATE 4/14/-19/88 SURFACE ELEVATION 22.3 LOCATION See Plate 2

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45	Ps		With some fine sand	-23.7	77.3			
	Vs		See below					
50	Ps		With some fine sand	-27.7				
	Vs		Firm to stiff dark gray organic clayey silt to silty clay, traces of fine to medium sand and gravel (OH)	-29.7		87	40	G,M Tx
55	Ps				62.9			
	Vs							
60	Ps				87.1			
	Vs							
65	Ps				64.0	85	38	G,M Tx
	Vs							
70	Ps				66.1	85	39	
	Vs							
75	Ps				66.3	80	39	G,M Tx
	Vs							
80	Ps		Trace peat	-57.7	142.7			
				-59.7				
	Vs							
85	Ps				49.4	64	33	G,M Tx
	Vs							
90			Continued on Sheet 3 of 3					

Completion Depth 106.5 Feet Water Depth * Feet Date 4/20/88

Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

LOG of BORING No. TB-107

DATE 4/14-19/88 SURFACE ELEVATION 22.3 LOCATION See Plate 2

DEPTH, ft.	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
90		17	Medium dense to dense dark gray silty fine to coarse sand and fine to coarse gravel with silty clay lenses (SM/SW)		21.6	29	19	M
					10.9			
95		36			10.9			
100		43			9.7			
			Very stiff multicolored (brown, red-brown, green, gray-green, pink) fine sandy clay (CL)	-80.2				
105		21		-84.2	19.0			
			* Drilled with mud, no water levels available					

Completion Depth 106.5 Feet Water Depth * Feet Date 4/20/88

Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

LOG of BORING No. TB-108

Sheet 1 of 3

DATE 4/29 - 5/3/88 SURFACE ELEVATION 22.7 LOCATION See Plate 2

DEPTH, ft.	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0		Soft to firm dark gray organic clayey silt to silty clay with mottled organic brown silty sand near surface (SM/OH)					
	3			65.5	91	43	
5	Ps			75.5			
	Vs						
10	Ps			66.4	95	49	G
	Vs						
15	Ps		5.7	27.0	NP	NP	
	Vs	Medium dense dark gray silty sand with little gravel, lenses of organic silty clay (SM/SW)					
20	8						
25	7			21.0			
30	3	Firm to stiff dark gray organic clayey silt to silty clay with trace to little sand and gravel, laminations of fine sand near top (OH)	-7.3	53.0			
35	Ps			51.6	70	40	
	Vs						
40	Ps			51.9			
	Vs						
45		Continued on Sheet 2 of 3					

Completion Depth 100.5 Feet Water Depth * Feet Date 5/4/88
Project Name DuPont - Cherry Island - Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

WCC - RP 1

LOG of BORING No. TB-108

Sheet 2 of 3

DATE 4/29-5/3/88 SURFACE ELEVATION 22.7 LOCATION See Plate 2

DEPTH, ft.	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER
44	Ps	Firm to stiff dark gray organic clayey silt to silty clay with trace to little sand and gravel (OH)		53.5			
	Vs						
49	Ps			41.0	47	25	
	Vs						
54	Ps			60.4			
	Vs						
59	Ps			64.4			
	Vs						
64	Ps			64.8			
	Vs						
69	Ps			30.2			
	Vs						
74	Ps			57.7	74	35	
	Vs						
79	Ps			82.3			
	Vs						
84	Ps			55.3			
	Vs						
89		Continued on Sheet 3 of 3					

Completion Depth 100.5 Feet Water Depth * Date 5/4/88
Project Name DuPont - Cherry Island - Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

LOG of BORING No. TB-108

DATE 4/29-5/3/88 SURFACE ELEVATION 22.7 LOCATION See Plate 2

DEPTH, ft.	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
89	Ps	See above	-67.3				
		Very dense dark gray to brown sandy gravel little silt, trace organic, becoming light gray silty sand (GW/SM)					
94	71			7.5			H
99	87		-76.3				
		Very stiff multicolored (gray, red-gray, green-gray, brown) clay with little sand (CH)	-78.8				
		* Drilled with mud, no water levels available					

Completion Depth 100.5 Feet Water Depth * Feet. Date 5/4/88

Project Name DuPont - Cherry Island - Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

WCC - RP 1

LOG of BORING No. TB-109

DATE 4/26-28/88 SURFACE ELEVATION 22.8 LOCATION See Plate 2

DEPTH, ft.	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0		Firm multicolored (red-brown, orange, dark gray) silt, trace organic matter, trace fine sand, trace mica (ML)					
	6		18.3	47.9			
5	Ps	Soft to firm dark gray organic clayey silt with trace gravel, trace mica (OH)		38.9	NP	NP	G,C H,T
	Vs						
10	Ps			72.3			
	Vs						
15	15			54.9			
		Medium dense dark gray coarse to fine sandy coarse to fine gravel, trace silt (GW)	4.8				
20	12			31.7			
25	45			13.7			
30	18			21.3			
35	12			33.6			
40	9			26.3			
		Dark gray organic clayey silt, trace fine to coarse gravel (OH)	-20.7				
45							

Continued on Sheet 2 of 3

Completion Depth 101.5 Feet. Water Depth * Feet Date 4/29/88

Project Name DuPont-Cherry Island-Cell 4 Project Number 88C2042B

Woodward-Clyde Consultants

WALTON CORPORATION
Drilling Contractor
P. O. BOX 1097, NEWARK, DELAWARE 19711

BORING LOG

: ....Cherry Island Expansion .... PROJECT NO. 78C005 ......
........Wilm., DE .... SUPERVISOR ....

NG NO. W-29	DRILLER S. Bethard	DATE 2-3-78
THER Sunny	SURFACE ELEVATION 24.97	DATUM

ple No.	Sample Depth - Feet From	Sample Depth - Feet To	Depth Strata Feet From	Depth Strata Feet To	Driller's Description of Materials	*Blows A		
1	1.0	2.5	0	3.0	~~Firm Gray Clayey Silt w/Brn.~~ Sand Lenses	2	2	2
2	4.0	5.5	3.0		Soft Dk. Gray Organic Clayey Silt	WH	1	1
3	6.0	7.0			Soft Dk. Gray Organic Clayey Silt	WH	WH	WH
4	9.0	10.5			Firm Di. Gray Org. Clayey Silt	WH	1	2
5	14.0	15.5		15.5	Gray C/F Sand & Gravel	1	2	4
			15.5					
6	19.0	20.5		22.0	Dense Gr. C/F Sand & Gravel	3	11	14
7	[illegible].0	25.5	22.0		M Dense Gr. C/F Sand Tr. Gravel	2	4	11
8	29.0	30.5			M Dense Gr. C/F Sand Tr. Gravel	6	12	9
9	34.0	35.5		39.0	M Dense Gray C/F Sand w/Gravel	4	7	7
10	39.0	40.5	39.0		~~Firm Dk. Gray Clayey Silt w/F~~ ~~Sand Lenses~~	1	2	2
11	44.0	45.5			Same	1	1	2
12	49.0	50.5			Same	1	2	2
13	54.0	55.5			Same	1	2	2
14	59.0	60.5			~~Firm Dk. Gray Clayey Silt w/F~~ ~~Sand Lenses~~	1	1	3
15	64.0	65.5		67.0	Same	1	2	2
16	69.0	70.5	67.0		~~Firm Dk. Gray Silty Clay w/Veg.~~	1	2	2
17	74.0	75.5			Same	1	2	2
18	79.0	80.5		80.5	Same Material	1	2	3

BLOWS ON CASING B
0- 1
1- 2
2- 3
3- 4
4- 5
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59-60
60-61

*Number of blows of 140 lb. hammer dropped 30 in. required to drive 2 in. split-spoon sampler for each of three increments.

Number of blows of 300 lb. hammer dropped 18 in. required to drive .... in. casing 12 inches.

....W/L on Rods @ 17.5

GROUND WATER

~~Caved~~	~~15.0~~	~~Moist~~

LOG of BORING No. W-32

DATE 2/13/78-2/14/78 SURFACE ELEV. 24.2 LOCATION See Plate 2

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0–5	2	Soft brown and gray clayey silt with vegetation	21.2	70.0			
5–15	0, 0, 1	Soft dark gray organic clayey silt	11.2	70.8, 77.5, 80.8			
15–20	4	Soft dark gray organic clayey silt with sand lenses	6.2	64.3			
20	19	Medium dense gray gravelly silty coarse to fine sand	2.2	28.1			M
25	20	Medium dense gray silty gravelly fine sand	- 2.8	42.8			
30–45	4, 2, 4, 2	Soft to firm dark gray organic clayey silt with sand lenses					

COMPLETION DEPTH ______ Water Depth ______ Date ______

SAMPLER: 3" O.D. SPLIT BARREL SAMPLER

LOG of BORING No. W-32 (con't.)

DATE 2/13/78-2/14/78 SURFACE ELEV. 24.2 LOCATION See Plate 2

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45–53	0	Soft to firm dark gray organic clayey silt with sand lenses	-28.8				
55–80	4, 3, 0, 2, 1, 1	Firm gray organic silty clay with vegetation	-56.3				

COMPLETION DEPTH 80.5' Water Depth 1.0' / 1.0' Date 2/14/78 / 3/ 1/78

SAMPLER: 3" O.D. SPLIT BARREL SAMPLER

A-9

45 LOG

JOB — 78 C 005

WCC RP 1

LOG of BORING No. W-33

DATE 2/21/78-2/24/78 SURFACE ELEV. 24.2 LOCATION See Plate 2

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	0						
5	0						
	0	Very soft to soft brown and gray clayey silt with vegetation					
10	0		10.7				
15	3						
20	5	Loose to medium dense gray silty medium to fine sand					
25	10		- 1.8				
30	3	Soft dark gray clayey silt with fine sand layers	- 8.8				
35	2						
40	5	Soft dark gray clayey silt with fine sand lenses	-18.8				
45	7	Soft dark gray clayey silt with fine sand layers		82.8			

COMPLETION DEPTH ______ Water Depth ______ Date ______

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

LOG of BORING No. W-33 (con't.)

DATE 2/21/78-2/22/78 SURFACE ELEV. 24.2 LOCATION See Plate 2

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45			-22.8				
50	3	87					
	P 0	Soft dark gray clayey silt with fine sand lenses		59.3	68	35	C T
55							
60	P 5		-35.8	65.9	81	35	
65	4			62.9			
70	P 0	Soft to firm gray silty clay with vegetation		62.7	78	33	C T
75							
80	P 5		-58.3	96.5	110	54	T
85							

COMPLETION DEPTH 82.5' Water Depth 1.5' / 2.0' Date 2/24/78 / 3/ 1/78

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

45' LOG JOB → 78 C 005

WCC RP 1

LOG of BORING No. W-35

DATE 2/15/78-2/16/78 SURFACE ELEV. 24.8 LOCATION See Plate 2

DEPTH, FEET	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0								
		2	Soft brown and gray clayey silt with vegetation		82.8			
5		P		18.8				
		0			56.4			
10		2	Soft gray clayey silt		85.5	113	48	
				11.8				
15		P	Firm gray clayey silt with fine sand lenses	8.8				
		3	Loose gray silty fine sand		39.8			
				5.3				
20		2			59.1			
25		3	Soft gray clayey silt with fine sand lenses		56.9			
				- 3.2				
30		2			66.5			
35		P	Soft to firm dark gray silty clay		73.4	67	30	T
		4						
40		3			53.6			
				-17.2				
45		65	Very dense gray coarse to fine sand and gravel	-20.7	14.3			

COMPLETION DEPTH 45.5' Water Depth 7.0' / 7.0' Date 2/16/78 / 3/ 1/78

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

LOG of BORING No. W-37

DATE 2/16/78-2/17/78 SURFACE ELEV. 24.0 LOCATION See Plate 2

DEPTH, FEET	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0								
		0						
5		0	Soft brown and gray clayey silt with vegetation					
		0						
10		P						
		2						
15		3		9.5				
20		2	Loose to medium dense gray silty fine sand, becoming silty coarse to fine sand with depth					
25		9						
				-4				
30		3			56.4			
		P						
35		1	Soft to firm dark gray clayey silt with fine sand lenses		60.0	68	35	
40		2			62.1	75	37	
45		P			60.5	66	34	C T

COMPLETION DEPTH Water Depth Date

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

JOB no. 78 C 005

45 LOG

LOG of BORING No. W-37 (con't.)

DATE 2/16/78-2/17/78 SURFACE ELEV. 24.0 LOCATION See Plate 2

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45	2	Soft to firm dark gray clayey silt with fine sand lenses					
50	1			69.4			
55	3			46.3	71	32	
			-35.5	31.2			
60	8	Loose to medium dense gray gravelly silty coarse to fine sand					
65	20		-41.5	11.8			
70							

COMPLETION DEPTH 65.5' Water Depth 2.5' / 2.5' Date 2/17/78 / 3/ 1/78

SAMPLER. 2" O.D. SPLIT BARREL SAMPLER

LOG of BORING No. W-38

DATE 2/14/78-2/15/78 SURFACE ELEV. 24.7 LOCATION See Plate 2

DEPTH, FEET	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0	2	Soft dark gray and brown organic clayey silt/silty clay					
5	2						
	0						
10	2						
15	2		6.7				
20	4	Firm dark gray organic clayey silt with fine sand lenses					
25	2						
30	*						
35	4						
40	5		-19.3				
45	81	Very dense gray silty sand and gravel	-20.8				

*Gas pocket encountered

COMPLETION DEPTH 45.5 feet Water Depth 2.0 feet / 2.0 feet Date 2/15/78 / 3/1/78

SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

A-12

45' LOG JOB No. 78 C 005

WC= RP 1

LOG of BORING No. W-40

DATE 2/13/78 SURFACE ELEV. 24.7 LOCATION See Plate 2

DEPTH, FEET	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
0		3						
5		3						
		2	Firm brown and gray clayey silt with vegetation					
10		4						
15		13		9.7				
20		4	Medium dense to loose gray gravelly coarse to fine sand becoming clayey silty coarse to fine sand					
				1.2				
25		3						
30		2						
35		3	Firm gray organic clayey silt with sand lenses					
40		3						
45		5		-20.8				

COMPLETION DEPTH ____ Water Depth ____ Date ____
SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

LOG of BORING No. W-40 (con't.)

DATE 2/13/78 SURFACE ELEV. 24.7 LOCATION See Plate 2

DEPTH, FEET	SAMPLES	SAMPLING RESISTANCE	DESCRIPTION	ELEVATION	WATER CONTENT, %	LIQUID LIMIT, %	PLASTIC LIMIT, %	OTHER TESTS
45				-20.8				
			Very dense silty coarse to fine sand and gravel					
50		72		-25.8				
55								

COMPLETION DEPTH 50.5' Water Depth 11.0' / 11.0' Date 2/13/78 / 3/ 1/78
SAMPLER: 2" O.D. SPLIT BARREL SAMPLER

JOB No. 78 C 005

WALTON CORPORATION

Drilling Contractor

P. O. BOX 1097, NEWARK, DELAWARE 19711

BORING LOG

ME .... Cherry Island Expansion .... PROJECT NO. 78C005

.... Wilm., DE. .... SUPERVISOR ....

RING NO.	DRILLER	DATE
W-46	S. Bethard	2-22-78
ATHER	SURFACE ELEVATION	DATUM
Cold		

mple No.	Sample Depth - Feet From	Sample Depth - Feet To	Depth Strata Feet From	Depth Strata Feet To	Driller's Description of Materials	*Blows A		
1	1.0	2.5	0	3.5	Brn. & Gray Silt w/Tr. Clay & Veg.	3	4	5
2	4.0	5.5	3.5		Soft Gray Organic Clayey Silt	1/1.0		1
3	6.0	7.5		9.0	Soft Gray Organic Clayey Silt	WH	WH	WH
4	9.0	10.5	9.0		Firm Fray Clayey Silt w/Tr. Sand & Veg.	1	1	2
5	14.0	15.5		15.0	Gray F Silty Sand	1	2	5
			15.0	17.0				
6	19.0	20.5	17.0	23.5	Gray Silty Clay w/Sand Lenses	3	5	3
7	24.0	25.5	23.5		Gray F/C Sand w/Some Gravel	4	8	11
8	29.0	30.5		33.5	Gray F/C Sand w/Some Gravel	9	6	6
9	34.0	35.5	33.5		Gray F Silty Sand w/Tr. Clayey Silt & Gravel	5	4	4
10	39.0	40.5		39.5	Gray Clayey Silt w/F Sand Lenses	3	2	4
			39.5					
11	44.0	45.5			Gray Clayey Silt w/F Sand Lenses	2	2	2
12	49.0	50.5		50.0	Gray F/M Sand w/Tr. Silt & Grav.	2	2	8
			50.0	53.5				
13	54.0	55.5	53.5		Firm Gray Clayey Silt w/Sand Lenses	1	3	4
14	59.0	60.5		63.0	Firm Gray Clayey Silt w/Sand Lenses	1	1	2

umber of blows of 140 lb. hammer dropped 30 in. required to drive 2 in. split-spoon sampler for each of three increments.

umber of blows of 300 lb. hammer dropped 18 in. required to drive .... in. casing 12 inches.

....

....

....

....

GROUND WATER

BLOWS ON CASING B
0- 1
1- 2
2- 3
3- 4
4- 5
5- 6
6- 7
7- 8
8- 9
9-10
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WALTON CORPORATION

Drilling Contractor

P. O. BOX 1097, NEWARK, DELAWARE 19711

BORING LOG

IE Cherry Island Expansion PROJECT NO. 78C005

Wilm., DE. SUPERVISOR

RING NO.	DRILLER	DATE
W-46 Continued	S. Bethard	2/22/28

ATHER	SURFACE ELEVATION	DATUM
Cold		

nple No.	Sample Depth - Feet From	Sample Depth - Feet To	Depth Strata Feet From	Depth Strata Feet To	Driller's Description of Materials	*Blows A		
5	64.0	65.5	63.0		Firm Gray Clayey Silt w/Tr. Sand & Organics	2	2	3
6	69.0	70.5			Gray Clayey Silt w/Tr. Vegetation	1	2	3
7	74.0	75.5			Gray Clayey Silt w/Some Veg.	2	2	4
8	79.0	80.5		80.5	Gray Clayey Silt w/Tr. Veg. & Brn. F Sand Lense	4	5	4

BLOWS ON CASING B
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umber of blows of 140 lb. hammer dropped 30 in. required to drive 2 in. split-spoon sampler for each of three increments.

lumber of blows of 300 lb. hammer dropped 18 in. required to drive .... in. casing 12 inches.

AR ....

GROUND WATER

14.0		

WALTON CORPORATI_N
Drilling Contractor
P. O. BOX 1097, NEWARK, DELAWARE 19711

BORING LOG

ME Cherry Isalnd Expansion PROJECT NO. 78C005

Wilm., DE SUPERVISOR

RING NO. W-47	DRILLER S. Bethard	DATE 2-24-78
ATHER Sunny	SURFACE ELEVATION	DATUM

mple No.	Sample Depth - Feet From	Sample Depth - Feet To	Depth Strata Feet From	Depth Strata Feet To	Driller's Description of Materials	*Blows A		
	1.0	2.5	0	2.5	Brn. & Gray Silt w/Tr. Clay &	2	2	2
					Veg.			
	4.0	5.5	2.5		Soft Gray Organic Clayey Silt	2	2	2
	6.0	7.5		8.5	Soft Gray Organic Clayey Silt	WH	WH	WH
	9.0	10.5	8.5		Firm Clayey Silt w/Some Org.	1	1	2
	14.0	15.5		18.5	Firm Gray Clayey Silt w/Some Org.	1	2	2
	19.0	20.5	18.5		Firm Gray Clayey Silt w/F Sand	WH	1	2
					Lenses			
	24.0	25.5		25.0	Gray Silt C/F Sand	WH	1	4
			25.0					
	29.0	30.5		32.5	Gray C/F Sand w/Tr. Gravel	17	11	4
	34.0	35.5	32.5		Gray F/M Sand w/Tr. Silt & Grav	13	9	13
)	39.0	40.5		40.0	Gray Clayey Silt w/Tr. Sand	10	7	3
			40.0					
	44.0	45.5		48.0	Gray Clayey Silt w/Tr. Sand	2	2	3
	49.0	50.5	48.0		Gray Clayey Silt w/Sand Lenses	1	2	2
	54.0	55.5			" " " " " "	1	2	2
	59.0	60.5		62.5	Gray Clayey Silt w/Sand Lenses	WH	2	2
	64.0	65.5	62.5		Gray Clayey Silt w/Tr. Veg.	1	1	3
	69.0	70.5			Gray Clayey Silt w/Tr. Veg.	1	1	3
	74.0	75.5			Same	2	2	3
	79.0	80.5		80.5	Gray Clayey Silt w/Tr. Veg.	WH	1	2

BLOWS ON CASING B
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umber of blows of 140 lb. hammer dropped 30 in. required to drive 2 in. split-spoon sampler for each of three increments.

Number of blows of 300 lb. hammer dropped 18 in. required to drive .... in. casing 12 inches.

AR .. Sample 8 ... 29.0-30.5 Large Piece of Gravel blocking drive shoe.

GROUND WATER

15.0	2/28/78

WALTON CORPORATION

Drilling Contractor

P. O. BOX 1097, NEWARK, DELAWARE 19711

BORING LOG

ME Cherry Island Expansion PROJECT NO. 78C005

Wilm., DE. SUPERVISOR

RING NO. W-48 | DRILLER S. Bethard | DATE 2-27-78

ATHER Cold | SURFACE ELEVATION | DATUM

mple No.	Sample Depth - Feet From	Sample Depth - Feet To	Depth Strata Feet From	Depth Strata Feet To	Driller's Description of Materials	*Blows A		
1	1.0	2.5	0	2.5	Brn. & Gray Silt w/Tr.Clay &Veg.	1	1	1
2	4.0	5.5	2.5		Gray Organic Clayey Silt Tr.Veg.	WH	1	1
3	6.0	7.5			Gray Organic Clayey Silt Tr.Veg.	1	1	1
4	9.0	10.5			Same	WH	1	1
5	14.0	15.5			Gray Organic Clayey Silt w/Veg.	WH	1	1
6	19.0	20.5		20.0	Gray Clayey Silt w/Sand & Grav.	1	4	5
			20.0	22.0				
7	24.0	25.5	22.0		Gray C/F Sand Tr. Silt	1	2	2
8	9.0	30.5		32.5	Gray C/F Sand Tr. Silt	3	4	3
9	34.0	35.5	32.5		Gray Fm.Clayey Siltw/Sand Lenses	2	1	2
10	39.0	40.5			Same	WH	2	2
11	44.0	45.5			Gray Firm Clayey Silt w/Sd.Lenses	1	2	2
12	49.0	50.5			Same	2	2	3
13	54.0	55.5			Same	1	2	3
14	59.0	60.5		63.0	Same	1	1	2
15	64.0	65.5	63.0	68.0	Firm Gray Silty Clay w/Tr. Veg.	1	1	3
16	69.0	70.5	68.0	73.5	Firm Gray Silty Clay w/Veg. & Sand	5	4	6
17	74.0	75.5	73.5		Firm Gray Silty Clay w/Veg.	2	2	3
18	79.0	80.5		80.5	Firm Gray Silty Clay w/Veg.	2	2	4

BLOWS ON CASING B	
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umber of blows of 140 lb. hammer dropped 30 in. required to drive 2 in. split-spoon sampler for each of three increments.

Number of blows of 300 lb. hammer dropped 18 in. required to drive .... in. casing 12 inches.

AP...

GROUND WATER

1.5	@ completion	

EXHIBIT B

PEAK STREAM FLOW FOR SHELLPOT CREEK

Peak Streamflow for the Nation

USGS 01477800 SHELLPOT CREEK AT WILMINGTON, DE

Available data for this site Surface-water: Peak streamflow GO

New Castle County, Delaware
Hydrologic Unit Code 02040205
Latitude 39°45'39.5", Longitude 75°31'07.3" NAD83
Drainage area 7.46 square miles
Gage datum 15.16 feet above sea level NGVD29

Output formats

Table
Graph
Tab-separated file
WATSTORE formatted file
Reselect output format

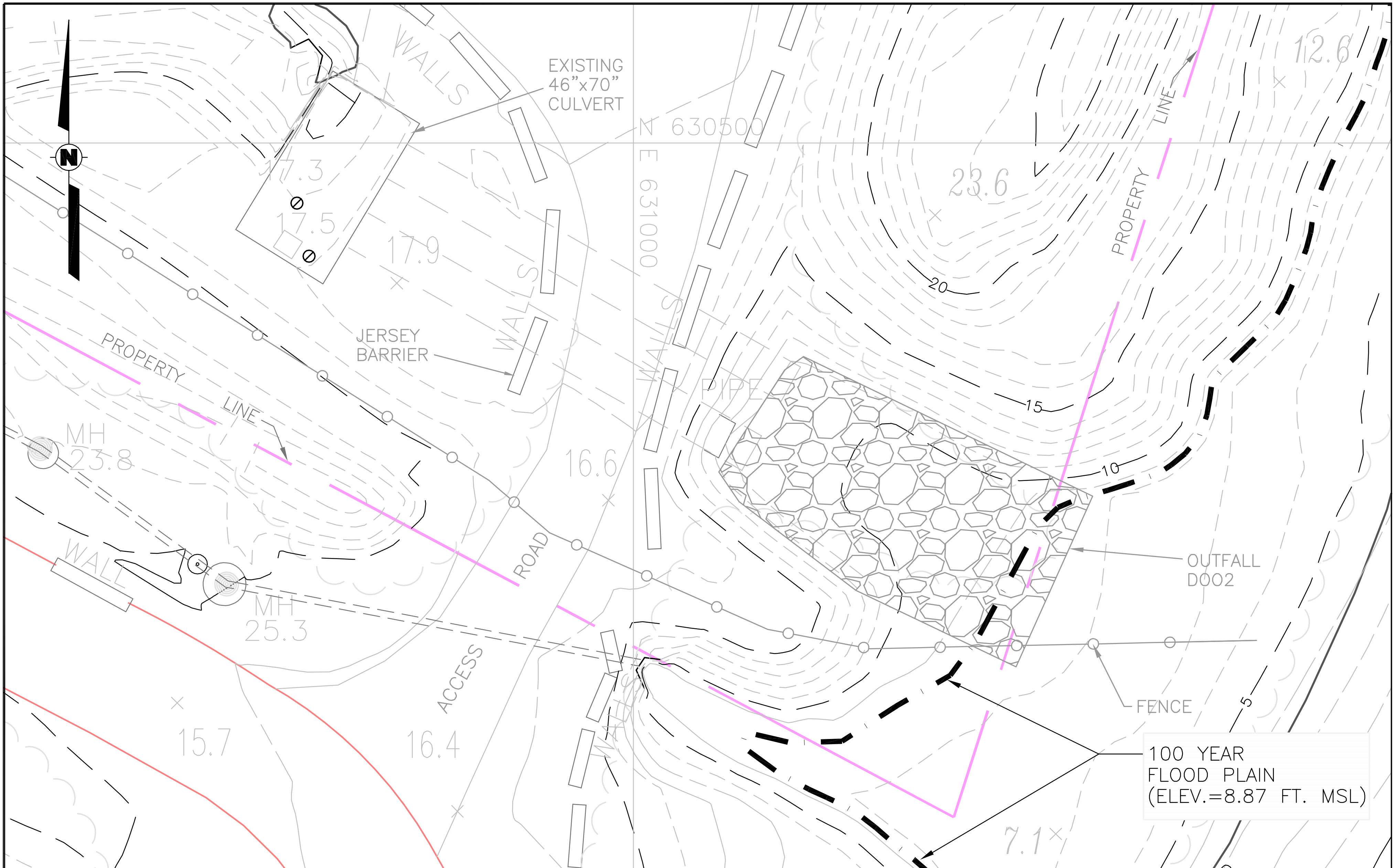
Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1945	Aug. 01, 1945	8.50	
1946	May 18, 1946	4.90	1,340
1947	May 01, 1947	6.52	2,140
1948	Nov. 04, 1947	5.13	1,440
1949	Dec. 30, 1948	3.63	715
1950	Aug. 03, 1950	3.35	565
1951	Nov. 25, 1950	4.80	1,290
1952	Jul. 09, 1952	8.60	4,080
1953	Jul. 23, 1953	3.83	785
1954	Dec. 14, 1953	3.92	830
1955	Aug. 18, 1955	6.73	2,280
1956	Jul. 21, 1956	4.92	1,330
1957	Nov. 02, 1956	4.27	1,000
1958	Apr. 06, 1958	4.55	1,140
1959	Jun. 02, 1959	5.34	1,540
1960	Sep. 12, 1960	6.12	1,930
1961	Apr. 13, 1961	4.68	1,210
1962	Mar. 12, 1962	3.72	730
1963	Aug. 01, 1963	3.37	560
1964	Jan. 09, 1964	4.31	1,020
1965	Jul. 11, 1965	4.24	990
1966	Feb. 13, 1966	3.65	695
1967	Aug. 27, 1967	9.10	4,650
1968	Dec. 03, 1967	4.71	1,220

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1976	Jul. 11, 1976	4.48	1,050
1977	Mar. 22, 1977	5.66	1,670
1978	Aug. 28, 1978	6.63	2,210
1979	Sep. 30, 1979	6.30	2,020
1980	Nov. 26, 1979	4.74	1,200
1981	Aug. 08, 1981	5.31	1,500
1982	Apr. 03, 1982	4.70	1,180
1983	Mar. 21, 1983	6.03	2,020
1984	Jul. 07, 1984	6.05	2,040
1985	Jul. 31, 1985	8.87	4,390
1986	Jan. 25, 1986	4.43	1,010
1987	Sep. 13, 1987	5.91	1,940
1988	Feb. 12, 1988	4.79	1,210
1989	Jul. 05, 1989	13.76	8,040
1990	Aug. 06, 1990	6.20	2,140
1991	Aug. 09, 1991	6.67	2,490
1992	Jul. 31, 1992	4.75	1,230
1993	May 31, 1993	5.58	1,700
1994	Jul. 26, 1994	8.26	3,830
1995	Jan. 20, 1995	4.93	1,330
1996	Jan. 19, 1996	5.85	1,890
1997	Jun. 13, 1997	5.60	1,720
1998	Jan. 23, 1998	5.29	1,530
1999	Sep. 16, 1999	8.95	4,460

1969	Sep. 03, 1969	4.42	1,080	2000	Jun. 28, 2000	6.32	2,230
1970	Aug. 01, 1970	6.20	1,970	2001	Jun. 16, 2001	4.95	1,340
1971	Sep. 13, 1971	11.91	6,850	2002	Jun. 24, 2002	3.75	660
1972	Jun. 22, 1972	6.66	2,240	2003	Jun. 20, 2003	8.75	4,270
1973	Jun. 29, 1973	6.31	2,030	2004	Jul. 12, 2004	8.74	4,260
1974	Aug. 23, 1974	8.00	3,300	2005	Apr. 02, 2005	6.17	2,120
1975	Mar. 19, 1975	5.08	1,390	2006	Jun. 02, 2006	8.02	3,620

EXHIBIT C

EXISTING CONDITIONS, SOUTHEAST CORNER, DUPONT HAY ROAD SLUDGE DRYING AREA



SCALE

20' 0 20'

Corporate Remediation Group

An Alliance between DuPont and URS Diamond

Barley Mill Plaza, Building 19
Wilmington, Delaware 19805

EXISTING CONDITIONS
SOUTHEAST CORNER

DuPont Hay Road
Sludge Drying Area
Edgemoor, Delaware

SCALE	DESIGNED	DRAWN	CAD FILE NO.
As Shown	J. Whitty	DEL	4767A001
DATE	CHECKED	APPROVED	FIGURE
2/21/07			1

EXHIBIT D

IAN PEGGS PAPER (2003)

GEOMEMBRANE LINER DURABILITY: CONTRIBUTING FACTORS AND THE STATUS QUO

Ian D. Peggs
I-CORP INTERNATIONAL, Inc.

Abstract
Regulators and engineers have sufficient confidence in the durability and long-term integrity of geomembrane lining systems to require their use as barriers between potential contaminants and groundwater. Yet experience with such lining systems covers only about 30 years. However, in that period adequate performance has been demonstrated. But how long will such geomembrane materials last before ultimate degradation or failure?

In the case of municipal solid waste landfills chemical dissolution and degradation of the typical high density polyethylene (HDPE) geomembrane is considered to be a non-issue. Ultimate durability will be a function of the stress cracking resistance of the specific HDPE resin used, the effectiveness of its antioxidation additives, the stresses generated in the geomembrane during installation and landfill operation, and the stress relaxation rate. The potential influences of each of these phenomena individually, and synergistically, on the lifetime of geomembranes are considered.

Introduction
It is interesting to note that environmentalists frequently claim that the plastic bags that float around in the oceans are a peril to wildlife for ever, yet they also claim that specially formulated and designed plastic based landfill lining systems are bound to fail in a relatively short time!

In our technical world the lifetimes of HDPE geomembranes in landfill lining systems have been variously estimated to be between 200 and 750 years. At the other end of the scale installed HDPE lining systems in other applications, typically exposed pond liners or cast-in concrete liners, have not lasted 6 months without failing. “Failing” is practically defined as developing a leak.

Of the many HDPE geomembrane liners that have “failed” in the past 20 years, all have failed in a very limited number of ways, but none have just “worn-out” or generally degraded to nothing, nor is it expected that they will. However, our practical experience with HDPE geomembranes is limited to about 25 years. Polyvinyl Chloride (PVC) has been evaluated after 30 years, and polypropylene (PP) is quite young at about 10 years. North American municipal solid waste (MSW) leachate is typically quite benign, as shown by the model for a standard testing leachate in Appendix A, to the extent that in the USA chemical resistance tests of HDPE are now rarely required. Many EPA 9090 “Compatibility Test for Wastes and Membrane Liners” tests have been performed with MSW leachates and none have been shown to damage the geomembrane – the degradative effect of MSW leachate on HDPE can practically be ignored.

HDPE liners in landfills and other applications fail or are made to fail as follows:

- Inadequate welding and attachment to structures
- Imposed stresses during construction
- Mechanical damage during construction
- Stress cracking at stress points
- Service stresses that separate welds

Except for poor welding and damage induced during installation HDPE geomembranes have generally only failed by stress cracking (a fundamental performance characteristic of HDPE) , or as a combination of oxidation followed by stress cracking (SC). Stress cracking is essentially a brittle cracking phenomenon that occurs at a constant stress lower than the short term yield strength or break strength of the material. It is a consequence of the semi-crystalline microstructure that gives the HDPE its good chemical resistance and high strength. PVC liners have cracked from loss of plasticizer at elevated temperatures and under ultraviolet radiation (UV) exposure, and PP has also experienced cracking at elevated temperatures but without UV exposure. However, PVC, PP, and LLDPE, are not susceptible to SC in the as-manufactured condition as is HDPE. Break times as a function of constant stress for five as-manufactured HDPE geomembranes are shown in Figure 1. At the higher stresses close to the yield stress, break occurs in a ductile manner. At lower stresses, below the knee in the curve, break occurs in a brittle manner – the ductile slope cannot be extrapolated to give a lifetime at a lower stress.

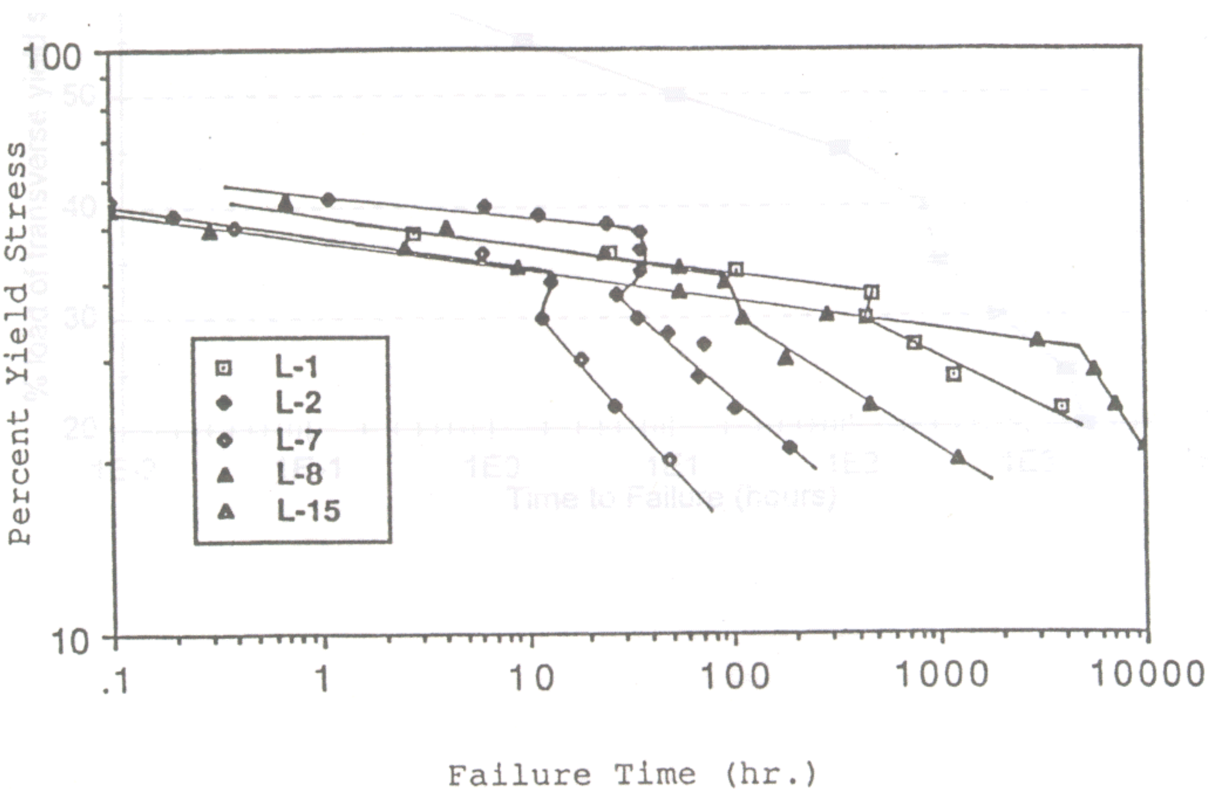


Figure 1 Stress rupture curves for five HDPE geomembranes (Hsuan et al. 1992)

It is frequently stated by some in the geomembrane and gas pipe industries (Peggs (2003)), Thomas (2002) Brown (1993)) that the only meaningful parameter that requires specification for HDPE is its stress cracking resistance (SCR). This is the only parameter that reflects the wide range of mechanical durabilities of geomembranes made from the different HDPE resins. All other index properties (tensile, puncture, and tear) are essentially identical in all HDPE geomembranes. Fortunately, as a result of the failures that have occurred, resins, geomembranes, and welding equipment/procedures used in landfill lining systems have significantly improved. LLDPE and PP do suffer from SC, but only when their antioxidants are depleted and they oxidize.

Such failures have been more evident in exposed lining systems in ponds, lagoons, and concrete basins where restrained contraction stresses are cyclic as temperatures change, where the geomembrane is not confined between two layers, where leakage is more evident, and where the damage can be seen. There have effectively been no known in-service failure events that have occurred in solid waste facilities in North America that cannot be ascribed to external influences. However, HDPE and PP have cracked on wrinkles under a hydrostatic head and there has recently been cracking in reinforced PP (RPP) on the underside of floating covers at the bottom of drainage troughs.

Double lining systems in US landfills that allow continuous monitoring of leakage flow rates through primary liners into the leakage collection, drainage, and removal systems (LCDRS) have shown no spikes related to punctures or liner degradation in service caused by events solely within or very close to the lining system. However, HDPE liner lifetimes considerably in excess of those experienced to date (maximum about 25 years) are desired and obtaining such lifetimes is the subject of this paper.

Discussion

Geomembrane liners are ideally designed to be installed without stress. They are simply intended to act as a barrier. Clearly, a zero stress installation is practically impossible to achieve – wrinkles are unavoidable. But without mechanical tensile stress a liner cannot be made to break and leak, making such an objective, or the means to tolerate it, desireable. However, while general chemical degradation due to leachate does not occur, the presence of chemicals such as chlorinated solvents, acids, and detergents in contact with a stressed HDPE geomembrane may result in environmental stress cracking (ESC) where the chemical accelerates the fundamental stress cracking phenomenon. ESC is taken advantage of in laboratory tests that are performed in a surface active detergent at elevated temperature (50^0C) to accelerate failures so they occur in a reasonable time, but without changing the fracture mechanism and morphology.

Impermeability

It must be recognized that nothing is absolutely impermeable. Apparent "leakage" may also occur through diffusion of vapor (solvent and water) through amorphous regions of the HDPE geomembrane, which then recondenses on the opposite side. Sangam and Rowe (2002), Park et al. (1995), and others have shown the diffusion rates of various organic liquids and solutions through geomembranes, but while these liquids are absorbed by the HDPE, which causes it to soften they do not cause a continuing and permanent degradation. When the liquid environment is removed the solvent vapors volatilize out of the geomembrane which recovers its original properties. In general the softening of the geomembrane while in service will be beneficial in allowing the liner to better conform to subgrade profiles and differential settlement without significant stress, thereby reducing the possibility of stress cracking. In fact the diffusing/absorbed organics act as a plasticizer for PVC which, when it dries out may then crack. Thus it remains flexible in service, but becomes brittle when exposed and tested. However, a similar phenomenon may have occurred in one case in which HDPE was exposed to creosote in a chemical resistance test - a 70% reduction in SCR was observed when the HDPE was removed from the creosote and all organics had desorbed. It is not known if this is a standard occurrence after exposure to organic liquids. In another case, in the presence of sulphuric acid, wrinkles in 3 mm and 5 mm thick HDPE liners caused by naphthalene, kerosene, and aromatic hydrocarbon absorption did suffer stress cracking as a result of oxidation caused by the acid at temperatures of about 70^0C.

Giroud and Bonaparte (1989) have shown (Table 1) that water vapor diffusion through 1 mm HDPE geomembrane with a head of 300 mm (the maximum allowed in MSW landfills), is approximately 0.8 lphd. Therefore no individual HDPE geomembrane can be considered absolutely leak free. This is the reason for the philosophy of double lining systems. Equivalent diffusion rates through LDPE and PVC geomembranes would be approximately factors of 45 and 115 higher due to their different densities and more amorphous microstructures. However, such diffusion "leakage" pales into insignificance compared to stone punctures and bulldozer blade rips.

Table 1: Water vapor diffusion through a 1 mm HDPE geomembrane

	Water depth on top of the geomembrane, h_w					
	0 m (0 ft)	0·003 m (0·01 ft)	0·03 m (0·1 ft)	0·3 m (1 ft)	3 m (10 ft)	>10 m (>30 ft)
Coefficient of migration, m_g (m^2/s)	0	9×10^{-20}	9×10^{-18}	9×10^{-16}	9×10^{-14}	3×10^{-13}
Unitized leakage rate, q_g						
(m/s)	0	9×10^{-17}	9×10^{-15}	9×10^{-13}	9×10^{-11}	3×10^{-10}
(lphd)	0	8×10^{-5}	0·008	0·8	80	260
(gpad)	0	8×10^{-6}	0·0008	0·08	8	28

In US landfills, analyses of primary leachates have shown them (Table 2) to be relatively benign, with pH values close to 7 and no high concentrations of any damaging components. By the time the components of the compacted bottle of detergent or solvent in the waste have drained to the level of the liner they are well diluted and do not cause an environmental stress cracking problem in the HDPE.

Table 2. Analysis of MSW landfill leachates (Tchobanoglous et al, 1993)

	Value, mg/L[b]		
	New landfill (less than 2 years)		Mature landfill (greater than 10 years)
Constituent	Range[c]	Typical[d]	
BOD_5 (5-day biochemical oxygen demand)	2,000–30,000	10,000	100–200
TOC (total organic carbon)	1,500–20,000	6,000	80–160
COD (chemical oxygen demand)	3,000–60,000	18,000	100–500
Total suspended solids	200–2,000	500	100–400
Organic nitrogen	10–800	200	80–120
Ammonia nitrogen	10–800	200	20–40
Nitrate	5–40	25	5–10
Total phosphorus	5–100	30	5–10
Ortho phosphorus	4–80	20	4–8
Alkalinity as $CaCO_3$	1,000–10,000	3,000	200–1,000
pH	4.5–7.5	6	6.6–7.5
Total hardness as $CaCO_3$	300–10,000	3,500	200–500
Calcium	200–3,000	1,000	100–400
Magnesium	50–1,500	250	50–200
Potassium	200–1,000	300	50–400
Sodium	200–2,500	500	100–200
Chloride	200–3,000	500	100–400
Sulfate	50–1,000	300	20–50
Total iron	50–1,200	60	20–200

Oxidation

The major environmental agency of concern in US landfills is oxidation. The Geosynthetic Research Institute has performed a number of thermal aging studies (Hsuan and Koerner (1998), Hsuan and Guan (1998)) to develop an estimated liner lifetime. Samples of different HDPE geomembranes were placed in ovens or simulated landfill environments at temperatures between 55 and 115⁰C for up to 2 years. Typical mechanical properties were periodically measured. The depletion of antioxidants was determined by measuring standard oxidation induction times (OIT) at 200⁰C and high pressure oxidative induction times (HP-OIT) at 130⁰C. Hsuan and Koerner (1998) heated five different geomembrane samples in forced-air ovens. The as-received OIT and HP-OIT values varied widely, again demonstrating the differences in durability between geomembranes from different manufacturers. Retained OIT values after aging at 65⁰C are shown in Figure 2, and changes in OIT and mechanical properties at 95⁰C are shown in Figure 3. The latter shows that mechanical properties are not changing as AO depletion occurs. Hsuan and Guan (1998) state that mechanical properties do not change until all AO has been consumed. An Arrhenius plot for OIT test data is shown in Figure 4 from which the activation energy for depletion of AO indicates that all AO is depleted at a service temperature of 20⁰ C in three of the geomembranes after approximately 60, 80, and 100 years. Note, again, that the different HDPE geomembranes behave quite differently. At the point of complete AO depletion the mechanical properties start to degrade. Thus there is another period after AO depletion during which the polymer itself degrades (oxidizes) and during which the measured property degrades to a defined critical level, often considered to be 50% of its original value. The time at which this occurs is termed the half-life.

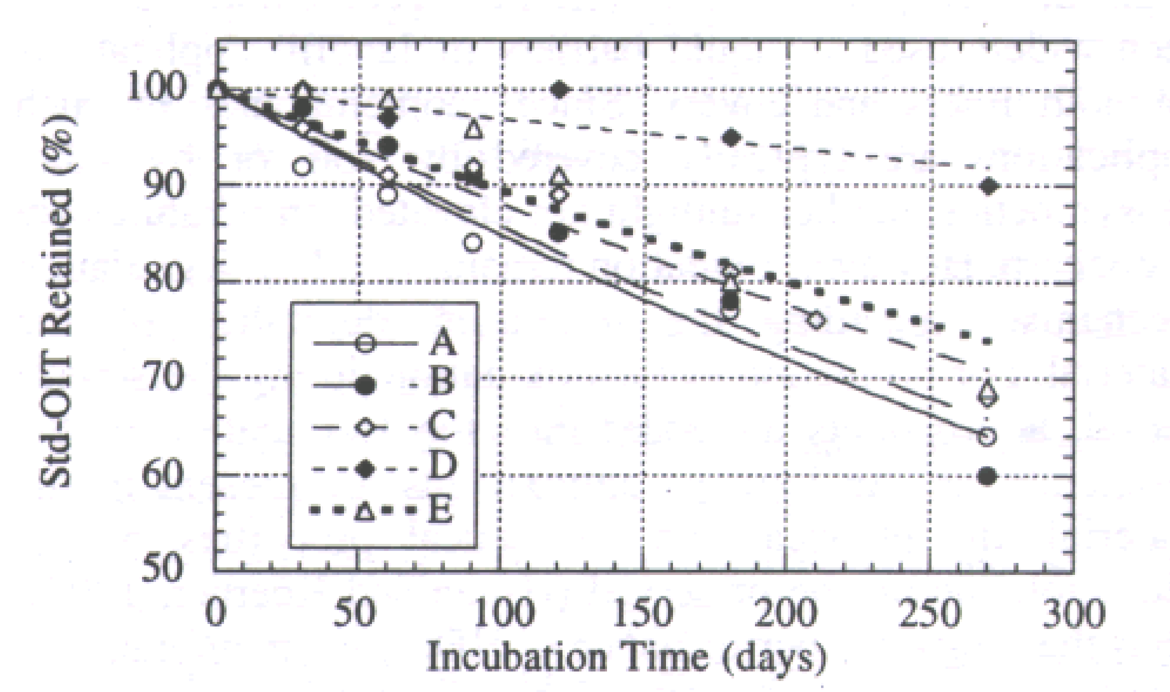


Figure 2 Aging at 65ºC

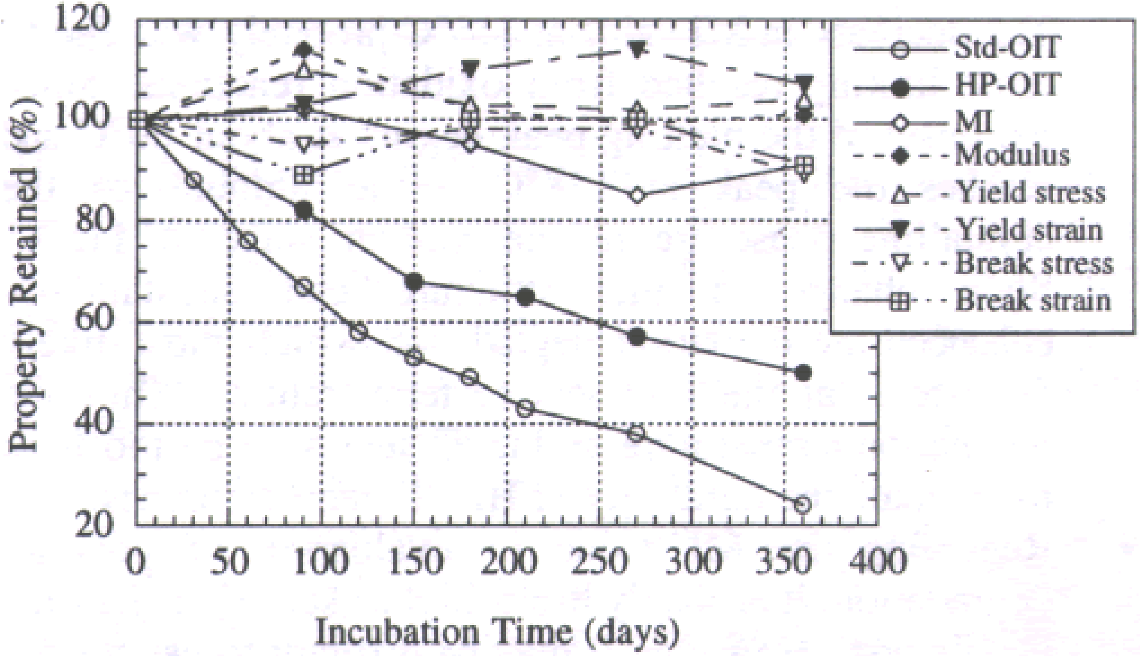


Figure 3 Aging at 95ºC

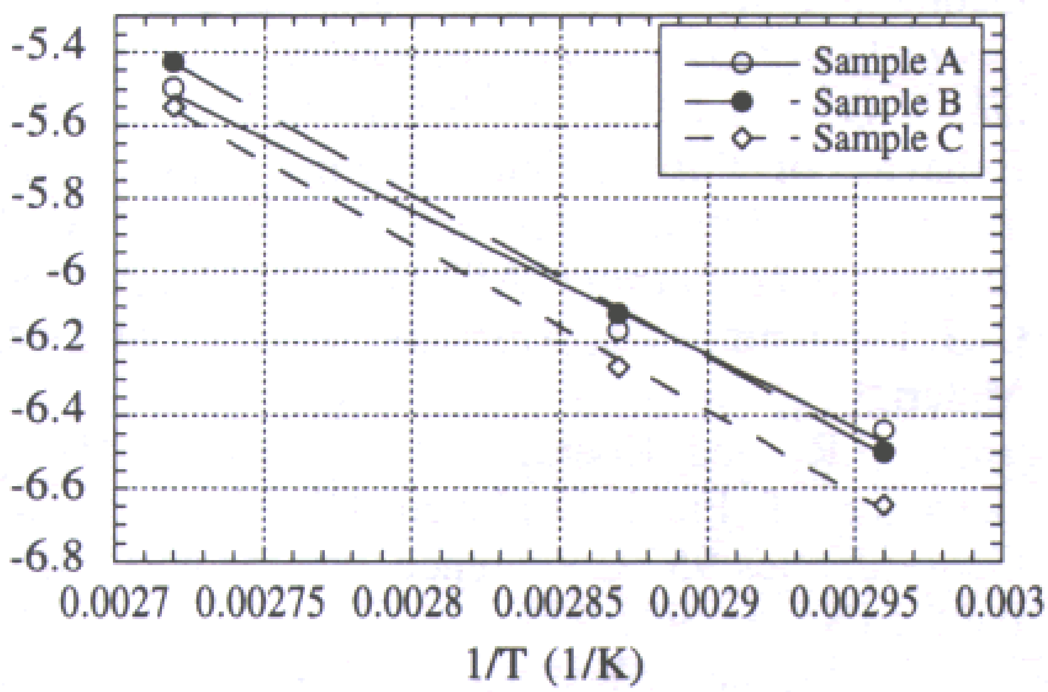


Figure 4 Arrhenius plot for OIT test data

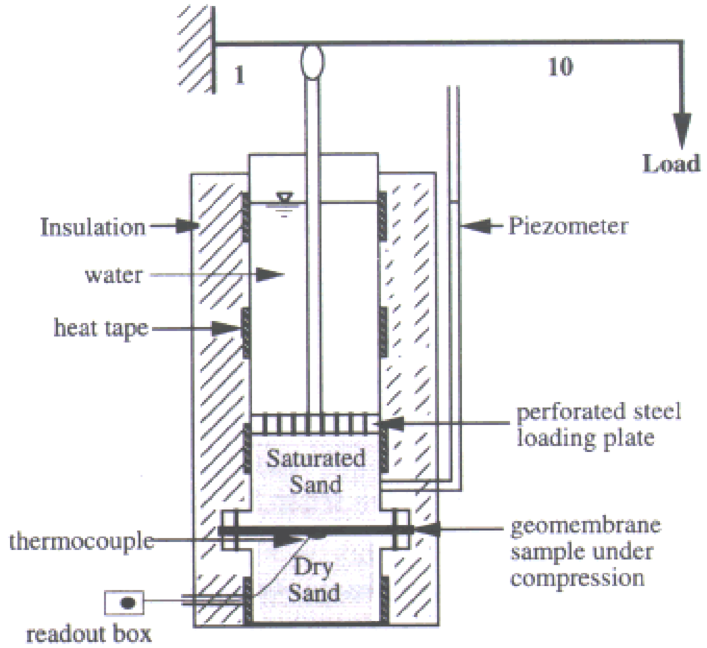


Figure 5 Equipment for aging in simulated landfill environment

Hsuan and Koerner (1998) report data on one HDPE geomembrane exposed in a simulated landfill environment as shown in Figure 5. The geomembrane sample was confined between two sand layers at a pressure of 260 kPa. A 300 mm head of water was maintained above the sample and the complete assembly was heated. Similar changes in properties were observed as shown in Figure 6. In this case the estimated time to AO depletion was calculated to be between 200 and 215 years. It is longer than in the laboratory tests because of the more limited access of fresh oxygen to the surface of the geomembrane in the confined environment. Aging procedures are still underway to assess the post-AO-depletion degradation of the material's properties.

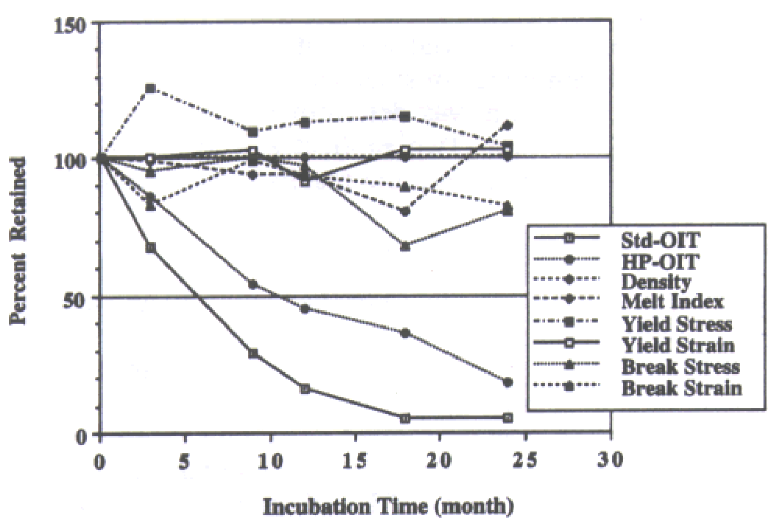


Figure 6 Changes in properties of geomembrane in simulated landfill environment

Hsuan and Koerner's (1998) hypothesis is that degradation of the geomembrane is a three stage process, as shown in Figure 7: 1) depletion of AO; 2) induction time to onset of polymer degradation, and; 3) degradation of the polymer and loss of mechanical properties. This will likely occur when samples are exposed without stress in an oven and under a uniform compressive stress in a simulated field environment. However, when the geomembrane is under tensile stress or has shear stresses imposed on/in surface layers at the same time as oxidation is occurring, the kinetics of degradation will not be as simple to model. Oxidation and SC will interact synergistically. Hessel (1990) indicates that when an HDPE specimen is thermally aged under stress it fails completely when the AO is consumed, as shown in Figure 8. At the higher stresses close to the yield stress the material fails in a ductile mode before oxidation occurs. At the intermediate stresses a premature (compared to ductile region extrapolation) brittle SC break occurs before oxidation occurs. But at the lower stresses when the AO is fully consumed and oxidation occurs before the extrapolated SC curve, break is even more premature. Therefore, there is a constant competition between the rate of depletion of AO and parallel or subsequent oxidation and the initiation of stress cracking as to which initiates failure first. In practice, oxidation within a continuously propagating and opening crack tip will further accelerate the crack growth rate.

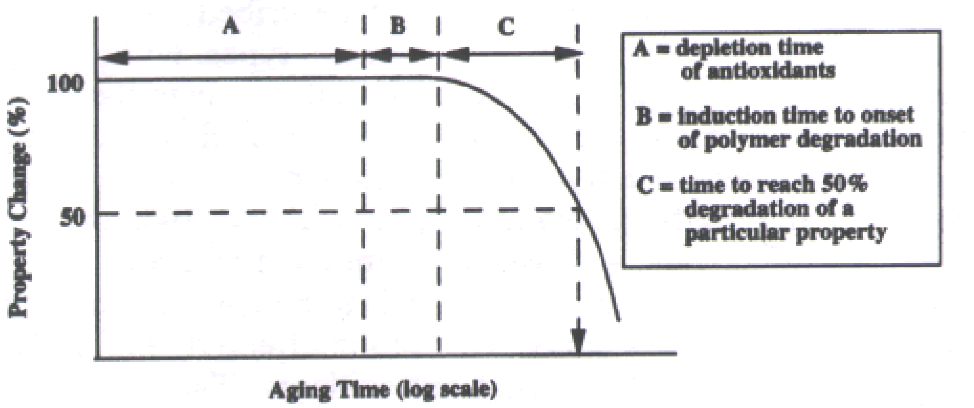


Figure 7 Stages of aging and degradation

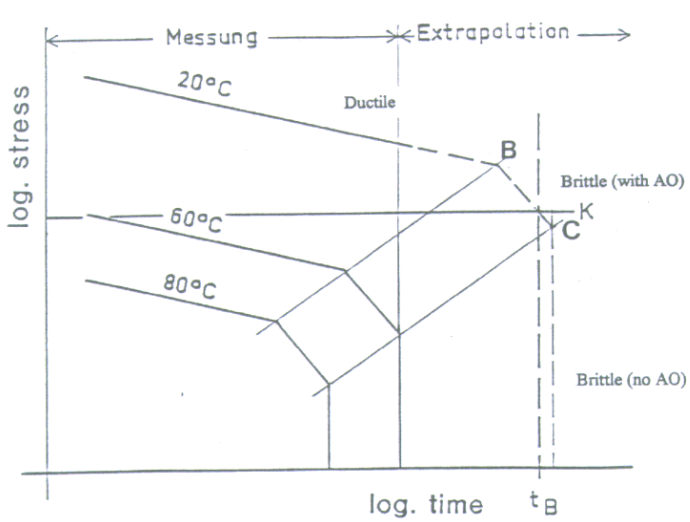


Figure 8 Stress rupture curves as a function of temperature

In fact, a conventional measurement of OIT will not indicate the true situation since oxidation will first occur on the surface where cracks will be initiated as soon as there is an adequately thick surface layer for the local stress to initiate a crack. When a conventional OIT test is performed, using the full thickness of the geomembrane as the specimen, the measured OIT will not be an indicator of the condition of the surface of the material. For instance if 10% of the thickness is fully depleted of AO the measured OIT will indicate a 90% retention of OIT, the same as if the complete thickness of the geomembrane were oxidized only 10% – not something that would normally cause concern. But, a completely oxidized surface layer and the cracks that would be initiated in it would be of concern. Thus there will be a continuing synergism between the kinetics of oxidation through the thickness of the geomembrane and the kinetics of stress cracking.

Stress Cracking Resistance

The significance of the rates of initiation of stress cracks on the surface of a geomembrane followed by crack propagation into the body of the geomembrane was further shown by Cadwallader (2001). He found that coextruded textured material made with a surface layer of low stress cracking resistance (apparently recycled polymer) would cause the accelerated cracking of core material with otherwise high SCR. Thus a core material that had a single point notched constant tensile load stress cracking resistance of over 1000 hr failed in 324 hr in an unnotched tests when coextruded with a textured surface layer made with inferior quality resin. The cracks were easily initiated in the textured surface layer but did not slow down when they met the core layer. Thus it is easier for a crack to propagate into a core layer than it is for a crack to initiate and propagate within that material alone. In general it was concluded that random surface textures may reduce the SCR of the basic smooth geomembrane. This will not occur in structured-surface geomembranes with their designed reproducible profiles on sheet of a uniform thickness.

In practice a confined HDPE geomembrane will only fail in the long term either by stress cracking at points of constant stress – stone protrusions, stresses across seams, creased wrinkles, textured surfaces. Stressed areas have also been seen at temporary dividing berms where the vertical pressure of waste has caused the berm to spread laterally on the continuous liner – there may be wrinkling on one side of the berm and significant tension on the other side

The author clearly has concerns about double textured liners on side slopes where there is a higher shear resistance on the top surface than on the bottom surface of the geomembrane with the result that the geomembrane becomes a load-bearing member of the system due to the induced shear stress. This is a major disconnect since on one hand the liner is designed to be without stress but on the other hand it is textured to hold soil on slopes. And, as indicated above, the presence of the surface texture will, at the same time, cause a reduction in the SCR of the geomembrane itself – to different degrees in the different types of textured and structured profiles. When a slide occurs on a slope and the geomembrane tears, it is always assumed that the geomembrane tears as a result of the soil movement. It is equally possible that the geomembrane may experience stress cracking, as a consequence of the induced shear stress, that initiates critical movement of the soil. All such geomembrane tears should be examined for regions of stress cracking within more extensive overload tears with their ductile elongations. Shear stresses induced in textured surfaces will be of much more significance in the forthcoming bioreactors with their higher temperatures and more extensive settlement along side slopes. The use of smooth top surfaces on geomembranes will have significant positive impact on the service life of a geomembrane – covering soils would better be provided with veneer stability by geogrids or high strength geotextiles, or by using an HDPE geomembrane with much higher SCR.

The kinetics of stress crack initiation and propagation increase at elevated temperatures as shown schematically in Figure 8. However, stress relaxation also increases as temperature increases resulting in a permanent race between stress cracking and stress relaxation as to which will prevail. If the induced stresses can be sufficiently reduced before cracking is initiated cracking will not occur. Also to be factored into this argument is oxidation of the geomembrane, for all HDPE geomembranes have required antioxidant additives that protect them against oxidation at the elevated temperatures during and after extrusion, during welding, during weld repairs, and during service. Once the additives are all consumed in providing protection, only very small tensile stresses will be sufficient to cause fracture.

The influences of the different textures and performance characteristics on the durabilities of HDPE geomembrane are reflected in recent work performed by Peggs et al. (2003b) to evaluate the maximum allowable strain in HDPE and other geomembrane materials used as a separation barrier between old waste and new waste in an MSW landfill vertical expansion. This work was done in response to the regulators requiring no more than 1% strain in the separation geomembrane independent of the polymer used. At another project the engineer was requiring an HDPE geomembrane in a lining system to experience no more than 0.25% strain at any location. This is practically impossible to achieve. These specifications are clearly a misunderstanding of the German BAM requirements (Seeger and Müller, 1996) for a maximum global strain of 3% and maximum local strain (at individual stone protrusions, for example) of 0.25%. More realistically, the following maximum strains are being recommended:

- HDPE smooth SCR<1500 hr 6%
- HDPE smooth SCR>1500 hr 8%
- HDPE random texturing 4%
- HDPE structured profile 6%
- LLDPE density <0.935 g/cm^3 12%
- LLDPE density >0.935 g/cm^3 10%
- LLDPE random texture 8%
- LLDPE structured profile 10%
- PP unreinforced 15%

The measurement of strain is used as an indirect measure of the stress that exists in a geomembrane that might result in stress cracking. While this is clearly important for HDPE, it is not as significant for other materials that are not susceptible to SC unless oxidized. The objective is to limit stress to a subcritical value where stress cracking will not be a practical problem. However in a confined situation the stress will be applied very slowly to the geomembrane as the adjacent soils move, and the geomembrane will be able to relax resulting quite rapidly in geomembrane stresses that are maybe 50 % of the value implied by the deformation.

Stress Relaxation

While the benefits of stress relaxation are apparent it is not a topic that has been thoroughly studied for geomembranes. Soong et al. (1994) investigated stress relaxation in a 1.5 mm thick HDPE geomembrane with initial stresses of 40, 50, and 60% of yield stress (at test temperature) and initial strains of 1, 3, and 5%, at temperatures between –10 and 70^{o}C. These were quasi-biaxial tensile tests using 100 mm wide by 50 mm gage length “wide width” tensile specimens. Initial loading was done quite quickly to minimize stress relaxation on loading. As shown in Figure 9 whatever the starting conditions, there was a trend to a very narrow range of final, but still significant stresses, after about 100 days. The relaxation modulus curves (stress/strain as a function of time) for a given starting condition could be superimposed into a master curve for a given relaxation temperature, as shown in Figure 10 for an initial 3% strain and a temperature of 10^{o}C.

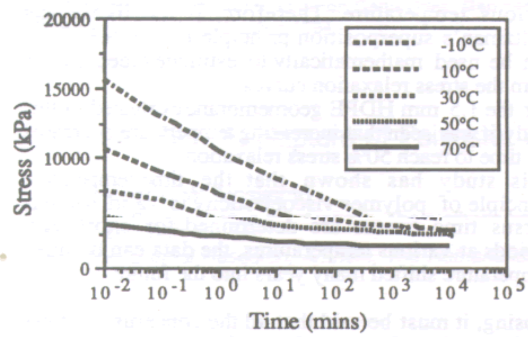


Figure 1 Results of stress relaxation test of 1.5 mm HDPE geomembrane started initially at 50% of yield stress at various temperatutes.

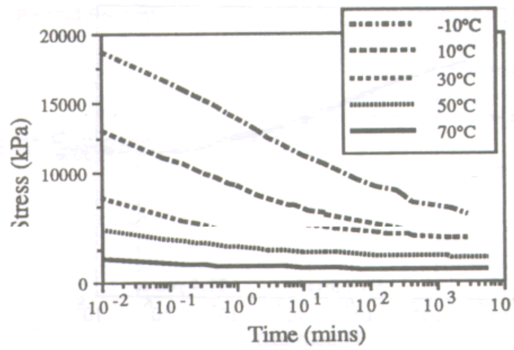


Figure 4 Results of stress relaxation test of 1.5 mm HDPE geomembrane started initially at 3% of strain at various temperatures.

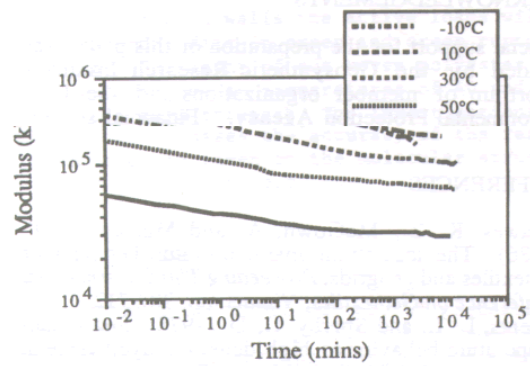


Figure 2 Stress relaxation modulus of 1.5 mm HDPE geomembrane corresponding to initial stress level of 50% of yield stress at various temperatures.

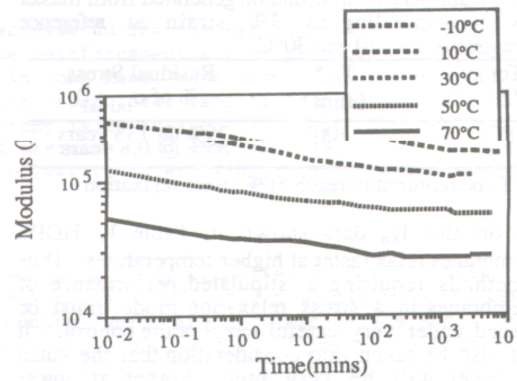


Figure 5 Stress relaxation modulus of 1.5 mm HDPE geomembrane corresponding to initial strain level of 3% of strain at various temperatures.

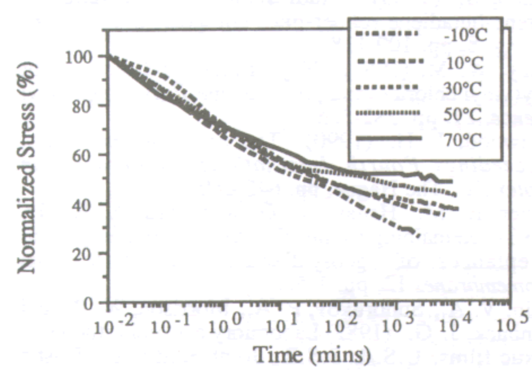


Figure 3 Normalized time-dependent stress of 1.5 mm HDPE geomembrane corresponding to initial stress level of 50% of yield stress at various temperatures.

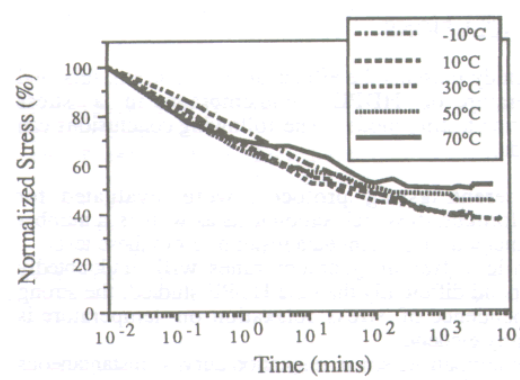


Figure 6 Normalized time-dependent stress of 1.5 mm HDPE geomembrane corresponding to initial strain level of 3% of strain at various temperatures.

Figure 9 Geomembrane stress relaxation data

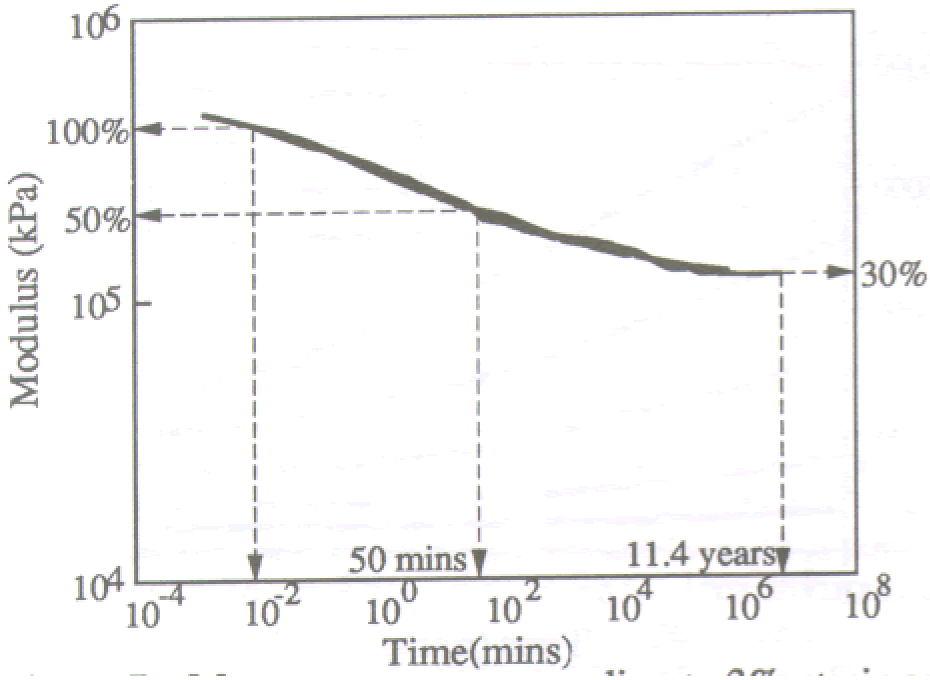


Figure 10 Master stress relaxation curve for 3% strain at 10°C

In this case 50% of the applied stress is removed by relaxation after 50 minutes with final equilibrium being achieved at about 30% of applied stress after 11.4 years. At higher temperatures the stress would relax more quickly. The equilibrium residual stress is between 2500 and 4000 kPa, between about 13 and 21% of the room temperature yield stress. Note that the strain was applied far more quickly than will occur during subgrade settlement, so in the landfill significant stress relaxation will occur during deformation. Soong et al. (1994) stated:

"Trial tests were performed initially to determine the suitable loading rate. The results suggested a rate of 12.7 mm/min as being appropriate…….. At slower rates a very significant amount of stress relaxation occurred during the loading process…."

Also, note that Soong et al. (1994) concluded:

"…… other HDPE geomembranes will undoubtedly respond differently than the HDPE studied……."

Thus all HDPE geomembranes are not the same, just as their SCR performances are not the same.

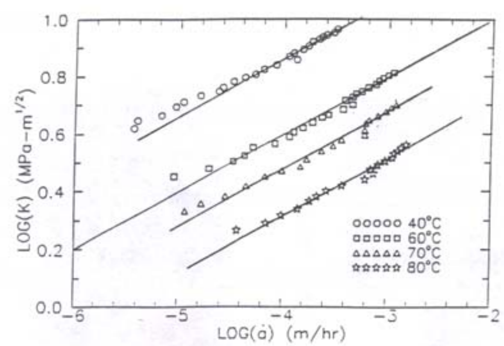
These stress relaxation rates compare well with those generated by Soong and Koerner (1997) for stress relaxation in waves in HDPE geomembranes under a uniform vertical loading. After 1000 hr at temperatures of 23, 42, and 55°C they found stresses relaxed between 60 and 78% leaving residual stresses of between 1% and 22% of the yield stress. Recollect that SC occurs below about 40% of the yield stress, in the range of these residual stresses. However, these tests were done under semi-confined conditions (waves raised off a flat support surface) while the Soong et al. (1994) tests were done under unconfined conditions. Under semi-confined conditions the residual stresses were lower than for unconfined specimens, possibly a result of the stress relaxation occurring during loading. Under fully confined conditions the residual stresses would probably be even lower.

Fracture Mechanics

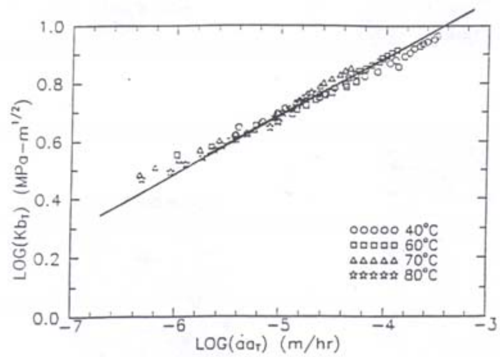
The HDPE natural gas distribution pipe research supported by the Gas Research Institute (now part of the American Gas Association) since the late 1970s has involved the development of fracture mechanics methodology to forecast lifetimes of high and medium density PE pipe and joints for system operating conditions – typically a well established internal pressure and temperature. Slow crack growth tests on laboratory specimens at elevated temperatures are used to develop empirical relations for the initiation and rate of crack growth as a function of a measure of the crack driving force and temperature. Kanninen et al. (1993) found that biaxial stress and temperature shifting rather than conventional uniaxial time temperature shifting (superpositioning) was more appropriate for gas pipe materials. This is because the semi-crystalline microstructure causes a change in strength of HDPE as temperatures change and this change also contributes to changes as a function of time. The shift functions for pipe HDPEs are very simple:

$a_T = \exp[-0.109(T_s-T_t)]$ for horizontal (time) shifting
$b_T = \exp[0.016(T_s-T_t)]$ for vertical (dependent variable) shifting

where T_s is an arbitrary (service) temperature (^{0}C) relative to a reference (test) temperature T_R. However, note that while these shift functions are the same for all MD/HDPEs tested the reference behaviors of the various PEs were different. As shown in Figure 11 rate curves and ductile/brittle transitions can be reproducibly shifted to any temperature within the variability of data generated at that temperature



(a) SCG data at various temperatures



(b) Consolidation of data at reference temperature of 40°C

Figure 11 Use of bi-directional shifting to consolidate SC data on HDPE gas pipe

The small amount of testing performed on geomembranes implied the same behaviour as for pipes and with very similar simple shifting functions. The mechanical durability of HDPE geomembranes would be a function of the resin used to manufacture the geomembrane, the geometry of the liner feature being evaluated (plain geomembrane, extrusion seams, fusion seams, textures/structures), the stress distributions, and the temperature. All these parameters synergistically influence the stress intensity factor responsible for crack initiation and propagation. They would be very difficult to predict for geomembranes, although simplifications could be made to assure lifetimes in excess of 100 years relatively quickly (Popelar et al. (1998).

The potential lifetime of an HDPE geomembrane as a result of crack initiation and propagation under a given set of environmental parameters has been initiated but is far from being finished. Along with the rate of AO depletion at service temperatures, this is the testing that will provide the data necessary to predict the durability of any given HDPE geomembrane. A start on applying the lessons learned from studies on HDPE gas pipe has been made by Kanninen, et al. (1992, 1993) who investigated the fracture mechanics of HDPE geomembranes and the possibility of performing accelerated tests at elevated temperatures then shifting rate curves to lower service temperatures. Two heuristic calculations were made of the lifetimes of a seamed geomembrane with stress cracks in the center of the weld and in the geomembrane at the edge of the seam (Figure 12) simply as a result of a lower service temperature compared to the installation temperature – i.e. as a result of contraction stresses. As shown in Figure 13, a stress crack approximately 0.2 mm deep would propagate through a liner at a temperature 3^{0}C lower than the installation temperature in approximately 1.5 yr. At a temperature difference of 12^{0}C final failure would occur in 0.3 yr. And at a 12^{0}C difference a stress crack 0.08 mm deep would have a failure time of about 0.4 yr, while a 0.3 mm deep crack would have a failure time of about 0.2 yr. While these scoping calculations generate very short crack penetration times it should be noted that baseline measurements were made on a material with low stress cracking resistance. The calculations also assume a constant load (no stress relaxation) and no confining pressures. Nevertheless, these calculations do show the ability of fracture mechanics, accelerated testing, and shifting of data to predict the failure times of specific HDPE geomembranes with given flaws in specific environments. Then, armed with a definition of critical flaw sizes, CQA monitors will become more effective and equipment can be developed to quantify observed defects and to mark them as critical or sub-critical. The latter need not be repaired. This is far better than the present blanket specifications which typically require no surface defect to exceed 10% of the thickness of the geomembrane while not having an instrument to easily measure it.

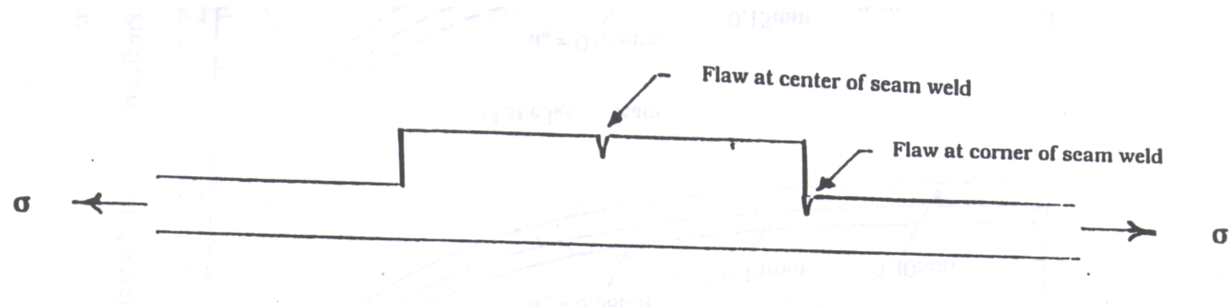


Figure 12 Model used in lifetime calculations

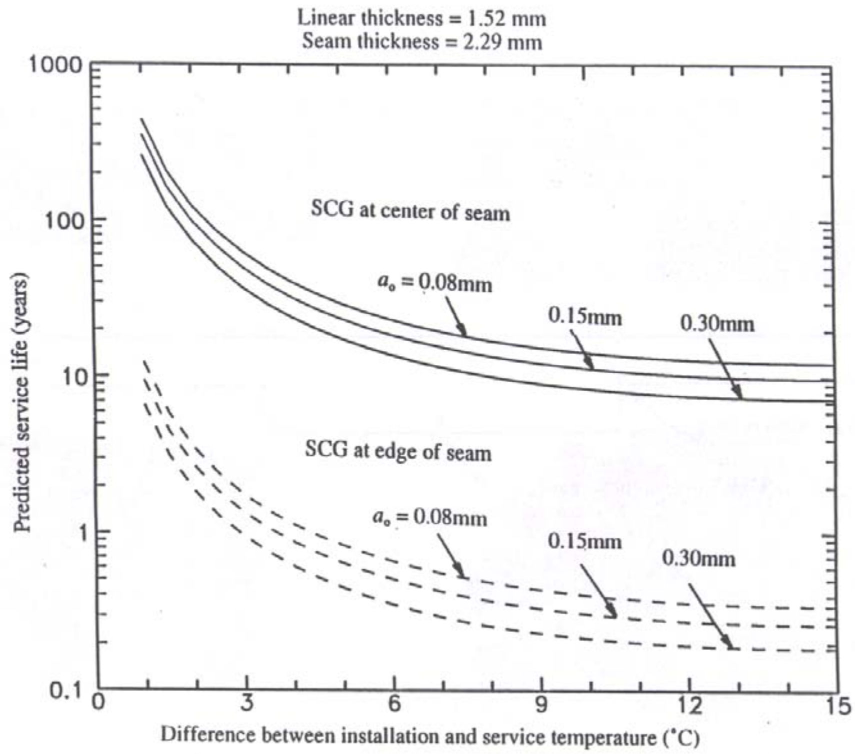


Figure 13 Break times at notches due to contraction stress

Specifications
At present protection against SC is typically considered to be provided if the geomembrane has a break time exceeding 200 hr in the ASTM D5397 notched constant tensile load test as promulgated in the Geosynthetic Research Institute GRI.GM13 standard "Test Properties, Testing Frequency and Recommended Warrant for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes" Revision 2, 1999. Some materials have break times of 250 hr, others have passed 10,000 hr without breaking. Thus, all HDPE's are not identical – some are far superior to others in their resistance to SC. These are the ones that should be used for maximum durability. Specifying "HDPE" for a critical geomembrane is akin to specifying "Steel" for bridge construction without identifying types and grades.

In the same GRI.GM13 standard adequate oxidation resistance is assumed if a decomposition time exceeding 100 min is obtained in the ASTM D3895 oxidation induction time (OIT) test. But this test performed at 200^{0}C does not necessarily reflect the oxidation resistance at lower service temperatures, since different AO packages have different components that protect the geomembrane over different temperature ranges, as shown in Figure 14. For example, phosphates only protect above 150^{0}C while hindered amine light stabilizers (HALS) only protect below 150^{0}C. Thus, a passing OIT at 200^{0}C does not necessarily guarantee acceptable behaviour at 80^{0}C, and vice versa. However, in most instances GRI has shown a relationship between oxidation rates at the two temperatures, but Peggs (2003) reports two instances where adequate SCR and OIT values did not result in adequate long term performance. In the first case an SCR of 240 hr and an OIT of 101 min did not prevent cracking of an HDPE geomembrane on exposed landfill liner slopes after 8 years. Cracks occurred on the longitudinal folds of the round-die manufactured geomembrane, in and along seams, and in the covering patch at burn-through protrusions. The material had lost all of its AO additives and had measured OITs of zero and 3 min.

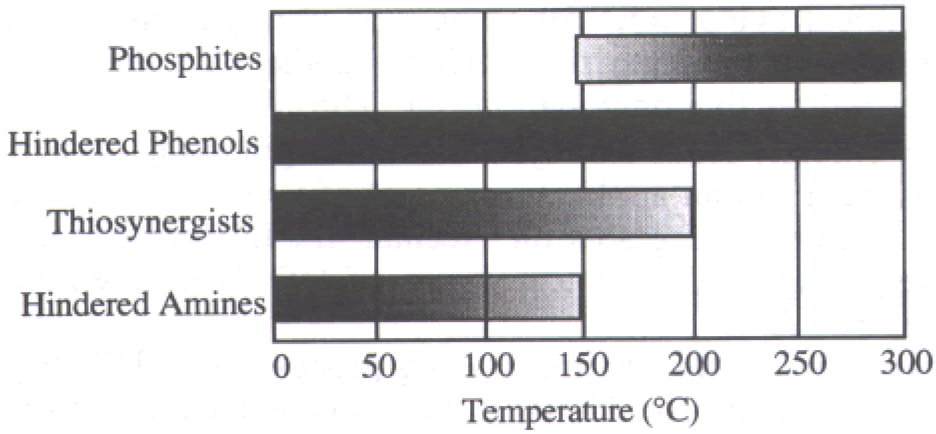


Figure 14 Effective temperature ranges of no additive components (Fay & King (1994))

In the second case a new HDPE geomembrane that had an SCR of 540 hr and an OIT of 240 hr , far exceeding the GRI.GM13 specifications, just met the specification for thermal aging (at 85^{0}C) but miserably failed the UV resistance test with a retained OIT of 35% compared to the specified >50% retained OIT. Thus there is much that we do not yet know about the oxidation rate of HDPE geomembranes at different temperatures.

Peggs et al. (2002) are attempting to develop a single material durability factor (MDF) that combines the SCR with an oxidation factor determined at 85^{0}C.   A Fourier Transform Infrared Spectroscopy specimen (simulating a thin surface layer on a bulk sample) is heated in an oven for a given time then the change in carbonyl group content, representative of oxidation, is monitored. It was found necessary to heat the specimen in an oxygen rich air stream at 90^{0}C for at least 24 hr in order to start seeing significant changes in the carbonyl group peak. More recent testing by Thomas (2003) suggests that testing at 85^{0}C in a high-pressure oxygen atmosphere may be necessary to generate sufficient oxidation in a thin specimen in a reasonably short time – 20 to 50 hr. Such an MDF will not quantify the time at which leaks will occur in a given lining system but it will facilitate a qualitative ranking of the durabilities of HDPE geomembranes made from different resins and with different AO packages. Then when experiments and calculations are made to determine the lifetime of one or two product, others can be scaled accordingly.

However, to further complicate matters, the exact combinations of circumstances that generate stress cracking are also not well established. In a pulp mill black liquor pond (effectively a confined situation) at an incoming liquor temperature of about 70^{0}C environmental stress cracking (due to detergent in the liquor) occurred at the tops of wrinkles in an indiscriminate fashion – small wrinkles on the floor were cracked but large kinked wrinkles at the toes of slopes were not. Intermediate wrinkles on the slopes also cracked indiscriminately. Therefore, it is impossible to predict the combinations of parameters that will generate environmental stress cracking.

Wrinkles have also caused problems in HDPE liners in concrete basins in mining facilities where cast-in liner has been used on walls and around the periphery of the floor, and loose liner has been used on the floor. Absorption of organic components of heap leach process solutions and swelling of surface layers has caused large wrinkles to build up against the peripheral weld between loose and anchored liner with the result that every millimeter of weld experiences a significant peel stress. The weakest segments of the welds have separated. That this happens may not be too surprising when liner seam specifications often allow one of the five peel and shear specimens to fail – a 20% failure rate. When such a seam has separated the long term durability of the liner is compromised even more because it is very difficult to make an effective repair weld on liner containing absorbed organics. Such repair/peel/repair/peel behavior continues. Ultimately the acid component of the elevated temperature solution might oxidize the liner with resultant stress cracking on the tops of wrinkles and along the edges of welds.

A survey of many colleagues reveals that none are aware of any leakage that has developed in a landfill bottom liner after a facility has been placed in service that is not due to external influences. However, a landfill in Minnesota had a bulldozer nick near a sump during construction that was repaired. The system, with waste on the floor, operated without any leak indication for about three months. Leakage then started at a rate of about 5000 lpd, equivalent to a hole of about 6 mm diameter under a 300 mm hydraulic head (Giroud and Bonaparte (1989)). Electrical leak surveys on top of 9 m of waste and die testing suggested that the leak was not at the same location as the sump and the repaired patch. Unfortunately, the suspected leak was not excavated to confirm its existence and to determine its cause. There have been a number of instances where leakage rates have suddenly increased after some time, but these have generally been found due to an increase in the primary leachate level above original defects in the liner that previously were not leaking.

Surveys by Bonaparte and Gross (1990) and others since then have showed that leakage rates through the primary liners of ponds and landfills vary significantly from effectively zero to quite significant values (3300 lphd). A typical Action Leakage Rate in US landfills at which leaks must be found and repaired is 200 lphd. This is not difficult to achieve. However, when a requirement for 70 lphd was not met at one hazardous waste project attempts to make repairs only resulted in a higher leakage rate. At a double lined concrete basin project a few drips from the leakage detection system was not considered satisfactory performance by the owner who insisted that repairs be made; the drips increased to a steady flow which could not be stopped. Surveys performed by Koerner et al. (2000) have shown (Figure 15) leakage rates at different stages of a landfill lifetime in different types of lining systems to taper off during closure to be very low – less than 1 lphd Koerner (2003 – personal communication) is not aware of any HDPE landfill liner that has developed a hole in service from anything other than an external influence, such as a bulldozer.

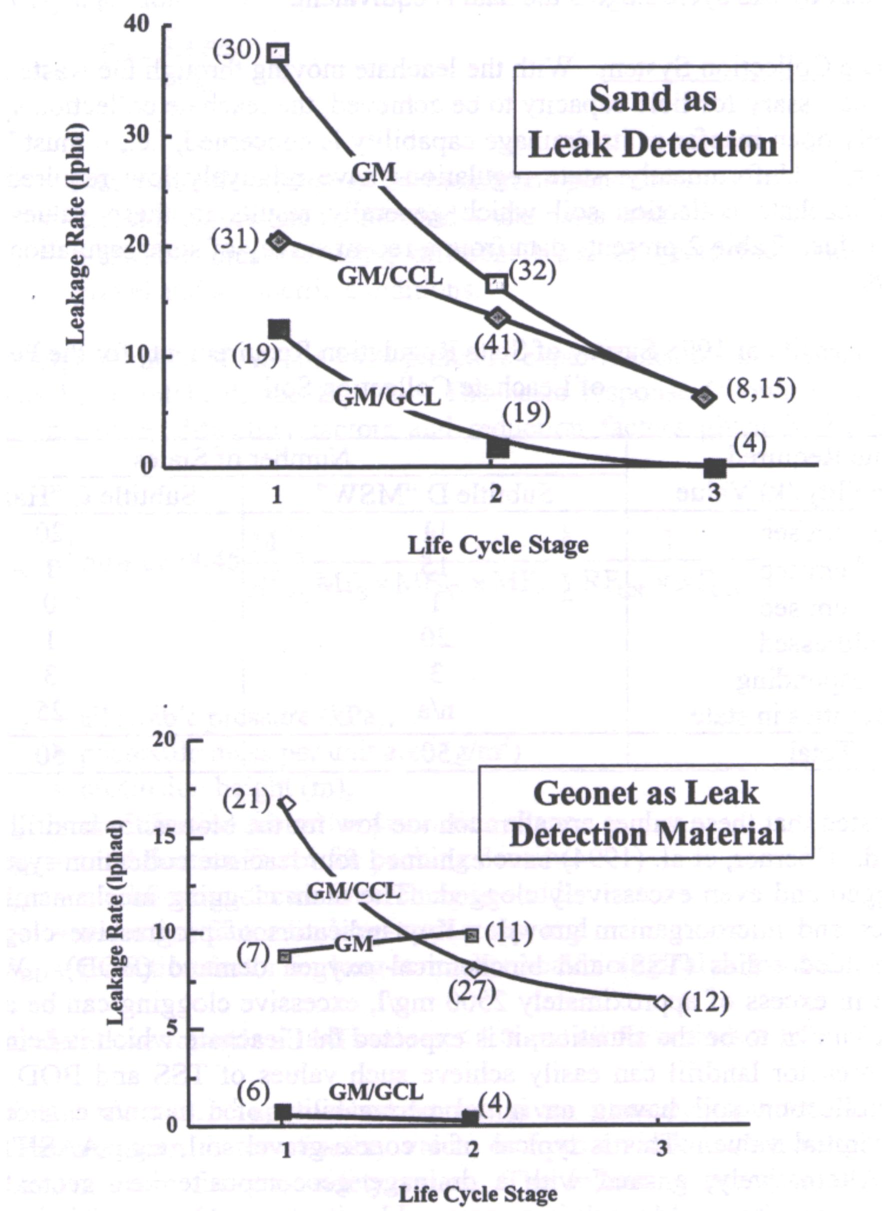


Figure 15 Primary liner leakage rates at different stages of landfill lifetime.

Stage1: Initial life Stage 2: Active life Stage 3: Post-closure

Nosko et al. (1996, 2000), and Rollin (1999) have clearly shown the locations, frequency, and causes of leaks made in liners during their installation, covering, and early stages of operation. Their data are summarized in Table 3 and Figure 16. In covered liners most damage (over 70%) is caused during placement of the cover soil, and only 24% of leaks occur in seams. However, in exposed liners almost 80% of leaks are on seams.

Table 3: Statistics of Liner Damage

WHEN/WHERE	AMOUNT	DETAILS	AMOUNT
Liner installation	24%	Extrusion	61%
		Melting	18%
		Stone Puncture	17%
		Cuts	4%
Covering	73%	Stone Punctures	68%
		Heavy Equipment	16%
		Grade Stakes	16%
Post-Construction	2%	Heavy Equipment	67%
		Construction	31%
		Weather, etc.	2%
Flat Floor	78%	Stones	81%
		Heavy Equipment	13%
Corner, Edge	9%	Stones	59%
		Heavy Equipment	19%
		Welds	18%
Under Pipes	4%	Stones	30%
		Welds	27%
		Heavy Equipment	14%
		Worker	15%
		Cuts	14%
Pipe Penetrations	2%	Welds	91%
		Worker	8%
		Cuts	1%
Road, Storage, etc.	7%	Heavy Equipment	43%
		Stones	21%
		Worker	19%
		Welds	17%

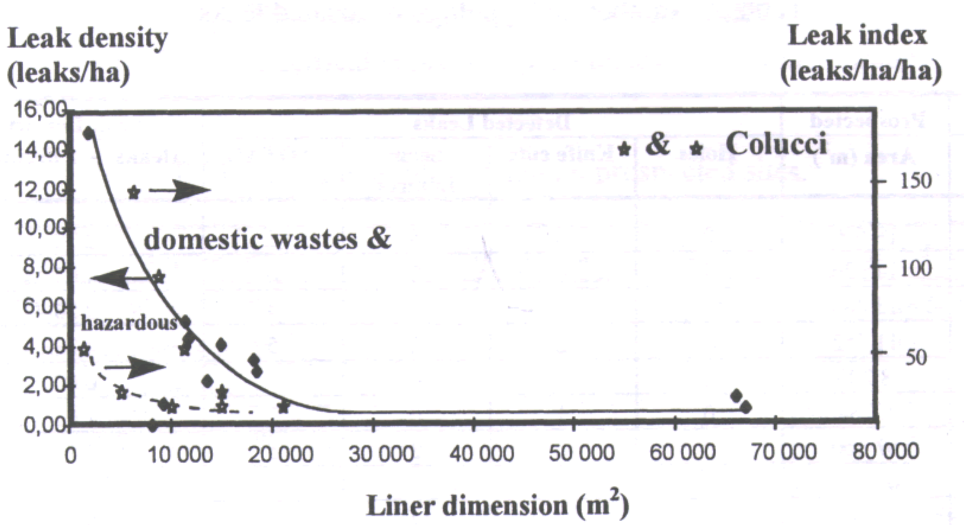


Figure 16 Frequency of leaks in primary geomembrane liners

Summary

In summary, an HDPE geomembrane used in a landfill is most unlikely to fail due to conventional chemical degradation as a result of being in contact with MSW leachates. HDPE geomembranes have adequate chemical resistance to endure and retain their integrity well beyond other factors that will cause a liner to fail. However, if the leachates contain unusually high concentrations of oxidizing acids, chlorinated solvents, or detergents that remain constantly on the liner for considerable times, environmental stress cracking may occur. By far the predominant mode of failure is due to man-induced damage during construction, such as stone punctures, bulldozer damage, and depth stake puncturing. When this type of damage is precluded or stabilized, premature failures will then only occur by simple stress cracking, or oxidation followed by stress cracking at regions of induced stress such as creases and wrinkles, stone protrusions, seams, textured surfaces, etc. The susceptibility of the liner to these kinds of stresses will be a function of the SCR of the specific resin used, and such resistances presently vary by a factor of about 500.

The durability of an HDPE geomembrane is a function of the following;

- The SCR and OIT of the resin used and of the geomembrane itself
- The knowledge of the design engineer in selecting and specifying the most appropriate HDPE, and designing the liner for minimum stress on slopes, at sumps, at penetrations, and in anchor trenches.
- The knowledge of the engineer in designing the system to accommodate the interim stresses between installation and design operating conditions
- The knowledge of the engineer in specifying adequate puncture protection for the geomembrane.
- The ability of the manufacturer to produce a consistent homogeneous material with a minimum number of internal and surface flaws and with effective antioxidation additives
- The smoothness, uniformity, and density of the subgrade
- The quality of the installation – lack of wrinkles, intimate contact with subgrade, seams, penetrations, minimum extrusion welding, minimum shear stress on slopes.
- Quality of CQA
- Placement of cover layers
- Operation of equipment on cover layers
- Placement of first layer of waste

If all of these items are optimized it is expected that an HDPE geomembrane in an MSW landfill should last for about 400 yr. Exposed liners are another matter altogether, clearly depending on the exposure conditions and requiring a better understanding of oxidation rates. Perhaps 75 years is an appropriate place to start. But lifetimes exceeding 100 years may not be necessary since, by then, there will be better things to do with present waste and it will be being mined with unusable components disposed of in better ways – maybe even atomized to nothing. Future generations will not want to maintain sealed cells of their forebears' waste, in the same way that there are presently very few infrastructures that we are using that are in their 1875 –1900 as-installed condition. We delude ourselves if we think we have the ultimate solution to waste containment and disposal. Nevertheless we should still target the maximum geomembrane and liner durability within existing technology.

Once a liner has successfully been installed and there is no leakage the only internal influences that can cause additional leaks are such things as:

- Wrinkles and protrusions causing SC before stress relaxation can occur

- Wrinkles at seams causing slow peel separation and propagation of critical, but not then penetrating, flaws in seams

- Crazes induced by peel separation initiating stress cracking at the stressed seam prior to stress relaxation occurring

- Shear and peel stresses at overheated and over-ground seams adjacent to wrinkles initiating stress cracking.

- Elevated geomembrane temperatures causing oxidation and accelerating stress cracking if stress relaxation is not accelerated in proportion.

- Stress cracking on slopes with randomly textured liner on the top surfaces prior to waste stabilization.

All of these possibilities can be minimized by the use of an HDPE geomembrane with high stress cracking resistance and good oxidation resistance. In practice, if settlement stabilizes and if no failures have already occurred it is unlikely that any subsequent failures will occur.

Conclusion

In practice, while one can make any number of aging and degradation calculations of lifetimes, half lives of specific index mechanical and physical properties, and activation energies, the practical performance of a lining system is presently controlled by human activities. Once the liner is installed and working without leakage the development of further leakage is a function of its stress cracking resistance, its oxidation resistance, the stresses generated, and the stress relaxation rate. The synergism between these performance characteristics is extremely difficult to predict. The most meaningful technique would be to use a fracture mechanics approach. However, as is evident, this still requires a significant amount of research effort. In assessing the development of flaws the most important thing to note is that all HDPEs are not the same - their mechanical durabilities can vary by a factor of 500. Specifying “HDPE” for a critical lining system is somewhat akin to specifying “Steel” for a bridge without identifying types or grades. Should the golf course decorative pond be lined with the same liner as a hazardous waste liquid pond as is presently done?

In the meantime, the best solution is to select a geomembrane with the highest stress cracking resistance and the best performance in the GRI.GM13 thermal aging test, and to install it carefully. Exposed liners will also require the UV resistance test. With a high SCR HDPE liner the emphasis will even more be on the care of design engineers, installation contractors, general contractors, CQA firms, and owners to ensure that the liner has no holes in it when it is placed in service.

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* * *

EXHIBIT E

TRANSPORTATION RISK CALCULATION (2007)

Exhibit E
Transport of Excavated IRM by Train from the Hay Street Site for Off-Site Incineration and Disposal

In the evaluation of remedy, implementation risks for the Hay Street IRM staging area, ENVIRON (2005) calculated the risk of transportation-related accidents, both fatal and nonfatal, resulting from the transfer of excavated IRM by truck to off-site incineration and disposal facilities. The current evaluation calculates the corresponding transportation-related risk of fatal and nonfatal accidents if the transfer were to occur by train instead of by truck. Whenever possible, to maintain consistency with the previous calculation of risk associated with transport by truck, the same assumptions were used in calculating the risk of fatal and nonfatal accidents due to hauling by train. Tables 1 and 2 show the calculations.

Based on statistics published by the Federal Railroad Administration (USDOT, 2007), the rates of transportation-related accidents using train hauling were calculated to be about 1.0 fatal accidents per million train-miles and about 7.3 nonfatal accidents per million train-miles. These accident rates were calculated by dividing the total number of accidents (either fatal or nonfatal) by the total number of miles traveled over the period 2003 through 2006 on Class 1 railroads. Statistics for Amtrak were not included because Amtrak is principally a passenger railroad.

As shown in the tables, approximately 120,000 train miles must be traveled under the off-site incineration and disposal scenario. This assumes that 500,000 tons of excavated IRM would be transported by train from the site to a permitted incinerator in East Liverpool, Ohio, and the incinerated material would then be sent to Model City, New York, for landfilling. The calculated risk of a transportation-related fatal accident under this scenario is 1 in 8. These estimates do not include the additional risk from hauling excavated material from the IRM site to the rail yard, which, assuming 89,000 total truck miles and an incidence of transportation-related fatalities of 1.1×10^{-6}, would add an additional fatality risk of about 1 in 3,000 (a negligible increase).

Consistent with the truck transportation analysis, the 1 in 8 risk of a fatal accident during train transport is based on round-trip miles. If it is assumed that rail transport would not require round trips by the trains, then the risk of a fatal accident would be reduced to about 1 in 16. If rail transport were used only between the site and the incinerator and truck transport were used between the incinerator and the landfill, then the overall risk of a transportation-related fatality would be between 1 in 8 and 1 in 16.

The calculated risk of transportation-related fatalities for truck-hauling was 1 in 13 (ENVIRON, 2005). Thus, the risk of a transportation-related fatality from train-hauling (i.e., in the range of approximately 1 in 8 and 1 in 16) is comparable to the risk of a transportation-related fatality from truck-hauling.

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Table 1: Predicted Incidence of Transportation-Related Fatalities: Transport of Excavated IRM by Train for Off-Site Incineration and Disposal

Symbol	Parameter Name	Units	Parameter Value	Basis
Mm	Mass of material to be transported	tons	500,000	DuPont
Mc	Capacity of railcar	tons	100	Engineering estimate
Nc (Nc=Mm/Mc)	Number of railcars needed	cars	5,000	Calculated
Nct	Number of railcars per train	cars	50	Assumption
Nt (Nt=Nc/Nct)	Number of trains required (one-way)	trains	100	Calculated
Ntrp	Number of trains required (round trip)	trains	200	Calculated
D	Length of designated route (one-way)	miles	600	Estimated from Mapquest.com. See note (1).
TMT (TMT=Ntrp x D)	Train miles traveled on designated route	train-miles	120,000	Calculated
Aft	Average fatality rate for rail freight transport	fatalities per train-mile	1E-06	Calculated from statistics for 2003-2006 published by Federal Railroad Administration, Office of Safety Analysis. See note (2).
Fs (Fs = Aft x TMT)	Predicted incidence of transportation-related fatalities	fatalities	0.12	Calculated
R (R=1/Fs)	Risk of Transportation-Related Fatality	fatality risk	1 in 8	Calculated

Notes

(1) Consistent with the analysis of potential risks associated with trucking of IRM from the Hay Street site (ENVIRON, 2005), this evaluation assumes that excavated IRM would be transported by train from the site to a permitted incinerator in East Liverpool, Ohio, and the incinerated material would then be sent to Model City, New York, for landfilling.

(2) Fatality rate calculated by dividing the total number of fatalities by the total train miles traveled during 2003-2006 on Class I railroads except Amtrak. Data retrieved from http://safetydata.fra.dot.gov/OfficeofSafety/ on February 27, 2006.

Table 2: Predicted Incidence of Transportation-Related Non-Fatal Accidents: Transport of Excavated IRM by Train for Off-Site Incineration and Disposal

Symbol	Parameter Name	Units	Parameter Value	Basis
Mm	Mass of material to be transported	tons	500,000	DuPont
Mc	Capacity of railcar	tons	100	Engineering estimate
Nc (Nc=Mm/Mc)	Number of railcars needed	cars	5,000	Calculated
Nct	Number of railcars per train	cars	50	Assumption
Nt (Nt=Nc/Nct)	Number of trains required (one-way)	trains	100	Calculated
Ntrp	Number of trains required (round trip)	trains	200	Calculated
D	Length of designated route (one-way)	miles	600	Estimated from Mapquest.com. See note (1).
TMT (TMT=Ntrp x D)	Train miles traveled on designated route	train-miles	120,000	Calculated
Anft	Average non-fatal accident rate for rail freight transport	non-fatal accidents per train-mile	7E-06	Calculated from statistics for 2003-2006 published by Federal Railroad Administration, Office of Safety Analysis. See note (2).
Fs (Fs = Anft x TMT)	Predicted incidence of transportation-related non-fatal accidents	non-fatal accidents	0.88	Calculated
R (R=1/Fs)	Risk of Transportation-Related Non-Fatal Accident	non-fatal accident risk	1 in 1	Calculated

Notes

(1) Consistent with the analysis of potential risks associated with trucking of IRM from the Hay Street Site (ENVIRON, 2005), this evaluation assumes that excavated IRM would be transported by train from the site to a permitted incinerator in East Liverpool, Ohio, and the incinerated material would then be sent to Model City, New York, for landfilling.

(2) Non-fatal accident rate calculated by dividing the total number of non-fatal accidents by the total train miles traveled during 2003-2006 on Class I railroads except Amtrak. Data retrieved from http://safetydata.fra.dot.gov/OfficeofSafety/ on February 27, 2006.

EXHIBIT F

ESTIMATED VOLUME OF PURE PHASE HEXACHLOROBENZENE IN IRM AND DM

Estimated Volume of Pure Phase Hexachlorobenzene in IRM and DM

Schnabel estimated that the amount of pure product ranges from approximately 10 and 90 L/m^3. However, when DuPont used the same basic calculation approach, the results indicate that Schnabel's estimates are not possible and are 1,000 times greater than the potential amount.

The following calculation provides an estimate of the upper limit for the potential amount of pure phase HCB in soil based on measured soil concentrations. Assuming there is no HCB in the dissolved phase, air phase, or sorbed phase (i.e., all HCB is in pure phase, a conservative assumption), the total soil concentration is related to the volume of pure phase HCB as follows:

$$C_{Total}\left(\frac{mg}{Kg}\right) = \frac{V_{HCB}(L) \times \rho_{HCB}\left(\frac{mg}{L}\right)}{V_{soil}(m^3) \times \rho_b\left(\frac{Kg}{m^3}\right)} \qquad (1)$$

where:
C_{Total} = total soil concentration (the measured soil concentration)
V_{HCB} = volume of pure phase HCB in soil sample
ρ_{HCB} = density of HCB
V_{soil} = volume of soil sample
ρ_b = dry bulk density of soil

In addition,

$$\rho_b = \rho_s \times (1-n) \qquad (2)$$

where:
ρ_s = density of soil solids
n = soil porosity

The rearrangement of Equations 1 and 2 yields the volume of pure phase HCB as a function of the soil HCB concentration:

$$V_{HCB}(L) = \frac{C_{Total}\left(\frac{mg}{Kg}\right) \times V_{soil}(m^3) \times (1-n) \cdot \rho_s\left(\frac{Kg}{m^3}\right)}{\rho_{HCB}\left(\frac{mg}{L}\right)} \qquad (3)$$

Note that Equation 3 provides an upper limit estimate of the potential volume of pure phase HCB in the soil sample. The actual amount will be lower because some of the measured HCB mass would be dissolved in the residual moisture of the sample, HCB would be sorbed to organic carbon in the soil, and some HCB would be in the vapor phase (if the soil is unsaturated). Despite this conservative approach, the calculated volume of pure phase HCB indicates that the volumes predicted by Schnabel are overestimated by a factor of about 1,000 (see Table 1A).

Based on the maximum measured soil concentration and a range of potential soil porosities, the estimated volume of "pure product" in the IRM is from 0.01L/m^3 to 0.09 L/m^3 (Table 1A), which is equivalent to 0.001% to 0.009% by volume.

For the DM, the estimated volume of pure phase is from 0.0005 to 0.001 L/m^3 (0.00005% to 0.0001% by volume) (see Table 1B). Thus, even these upper-limit calculations indicate that pure phase HCB is essentially absent from the DM.

Physical Properties and Immobility of Hexachlorobenzene in IRM and DM

The above calculations demonstrate that without consideration of other factors, the presence of pure HCB in the IRM would be1,000 times less than the estimates provided by Schnabel and that these potential volumes of HCB are negligible to nearly zero. Further, because the melting point of HCB is 231°C (448°F) (http://www.atsdr.cdc.gov/toxprofiles/tp90.html) at these levels, HCB would be present in solid form (as white crystalline solid). Therefore, the HCB is not a NAPL that will migrate from the IRM or DM, as suggested by Schnabel.

HCB has a very high organic carbon partition coefficient and is therefore strongly adsorbed to the carbonaceous IRM, the carbon fraction of the DM, and to soil organic matter. Therefore, it is generally considered to be immobile with respect to leaching (http://www.atsdr.cdc.gov/toxprofiles/tp90.html). Past TCLP analysis of IRM confirms this. In addition, the solubility of HCB is 0.006 mg/L, which is extremely low. (For comparison, consider the common groundwater contaminants benzene and trichloroethylene, which have a solubility of 1,750 mg/L and 1,000 mg/L, respectively.) Therefore, even for the remote possibility that significant infiltration penetrates the capping material and seeps through the IRM, there is no risk to groundwater contamination because the solubility limit for HCB is over 300 times less than the RAO of 1.9 mg/L.

Conclusions

The above calculations and discussion clearly demonstrate that any residual HCB that is present in IRM and DM does not pose a risk to current or future groundwater quality.

TABLE 1A

Estimated Volume of Pure-Phase Hexachlorobenzene (V_{HCB}) in 1 m^3 of Iron Rich Material

	(Based on C_{Total} = 54.96 mg/Kg)[a]		(Based on C_{Total} = 12.37 mg/Kg)[a]	
n	Schnabel Report V_{HCB} (L)	This Report (Equation 3) V_{HCB} (L)	Schnabel Report V_{HCB} (L)	This Report (Equation 3) V_{HCB} (L)
0.20	94.64	0.09465	21.29	0.02130
0.25	88.72	0.08873	19.96	0.01997
0.30	82.81	0.08282	18.63	0.01864
0.35	76.89	0.07690	17.30	0.01731
0.40	70.98	0.07099	15.97	0.01598
0.45	65.06	0.06507	14.64	0.01465
0.50	59.15	0.05915	13.31	0.01331
0.55	53.23	0.05324	11.98	0.01198
0.60	47.32	0.04732	10.65	0.01065

ρ_s (Kg/m^3) = 4,400 [b]

ρ_{HCB} (mg/L) = 2.044×10^6 [c]

V_{soil} (m^3) = 1.0

TABLE 1B

Estimated Volume of Pure-Phase HCB (V_{HCB}) in 1 m^3 of Dredge Material

	(Based on C_{Total} = 1.1 mg/Kg)[a]	
n	Schnabel Report V_{HCB} (L)	This Report (Equation 3) V_{HCB} (L)
0.20	1.05	0.00105
0.25	0.99	0.00099
0.30	0.92	0.00092
0.35	0.86	0.00086
0.40	0.79	0.00079
0.45	0.72	0.00073
0.50	0.66	0.00066
0.55	0.59	0.00059
0.60	0.53	0.00053

ρ_s (Kg/m^3) = 2,450 [d]

ρ_{HCB} (mg/L) = 2.044×10^6 [c]

V_{soil} (m^3) = 1.0

Notation:

- C_{Total} = measured soil HCB concentration
- V_{HCB} = volume of pure-phase HCB
- ρ_s = density of soil solids
- ρ_{HCB} = density of HCB
- V_{soil} = volume of soil
- n = porosity
- mg = milligram
- Kg = kilogram
- L = liter
- m^3 = cubic meter

Equation 3:

$$V_{HCB}(L) = \frac{C_{Total}\left(\frac{mg}{Kg}\right) \times V_{soil}\left(m^3\right) \times (1-n) \cdot \rho_s\left(\frac{Kg}{m^3}\right)}{\rho_{HCB}\left(\frac{mg}{L}\right)}$$

References:

a Lancaster Labs

b Schnabel Report (Table 5-1)

c http://www.atsdr.cdc.gov/toxprofiles/tp90.html

d Schnabel Report (Table 5-2)

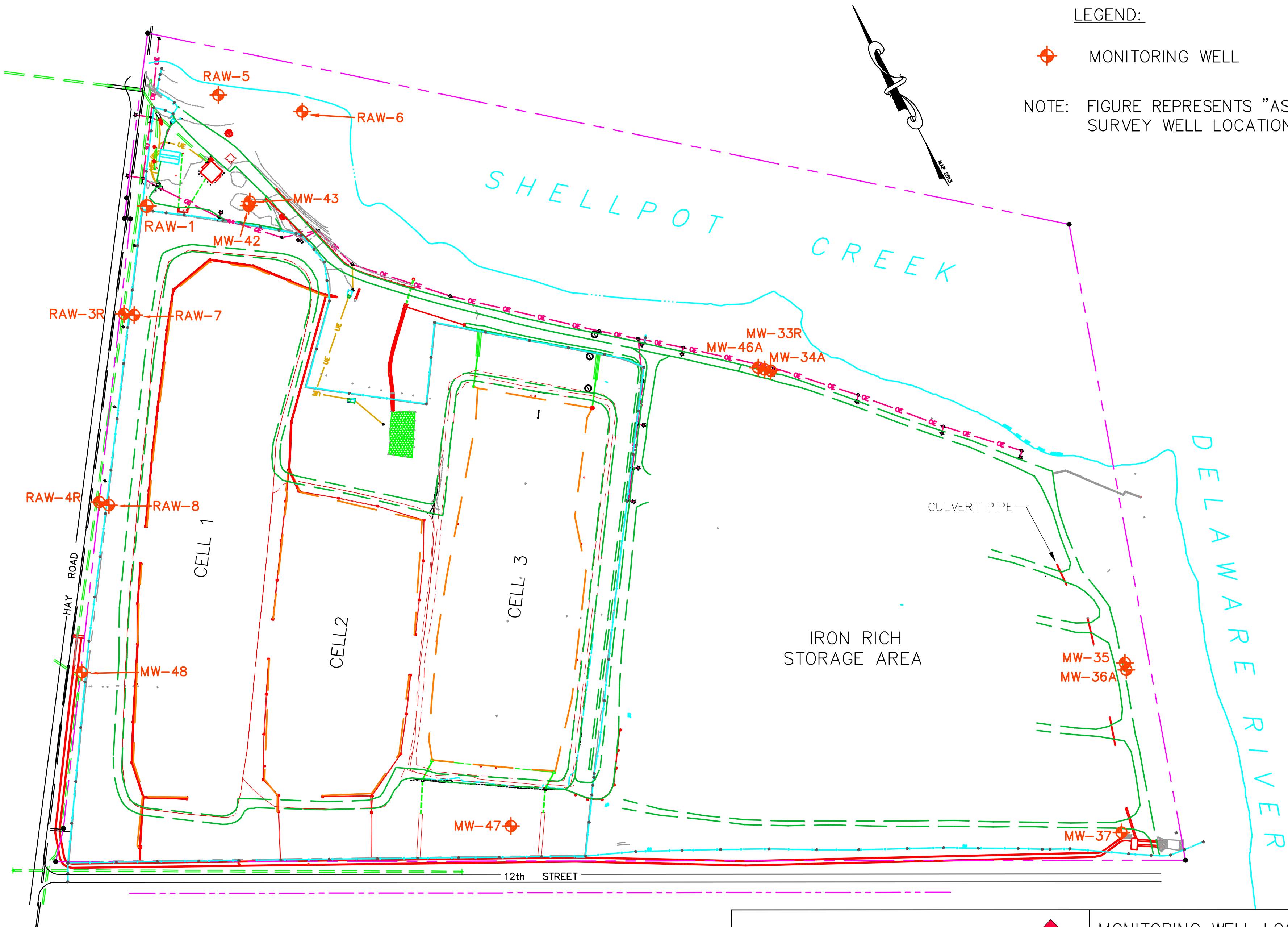
EXHIBIT G

MONITORING WELL LOCATION MAP

LEGEND:

MONITORING WELL

NOTE: FIGURE REPRESENTS "AS-BUILT" SURVEY WELL LOCATIONS



SCALE

350 0 350'

Corporate Remediation Group

An Alliance between DuPont and URS Diamond

Barley Mill Plaza, Building 19
Wilmington, Delaware 19805

MONITORING WELL LOCATION MAP

DuPont Hay Road Landfill
Edgemoor, Delaware

SCALE	DESIGNED	DRAWN	CAD FILE NO.
As shown	KNJ	DEL	7109A032a
DATE	CHECKED	APPROVED	FIGURE
1/25/07			2

EXHIBIT H

IRON-RICH 101 CHLORIDE LEACHABILITY STUDY REPORT (1992)

IRON-RICH 101 CHLORIDE LEACHABILITY STUDY REPORT

Du Pont Edge Moor Facility
Edge Moor, Delaware

October 19, 1992 **DERS Project No. 1205**

Prepared by

Du Pont Environmental Remediation Services
Bellevue Park Corporate Center
300 Bellevue Parkway, Suite 390
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CONTENTS

FIGURES

TABLES

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(Continued)

1.0 INTRODUCTION

The purpose of this report is to discuss the results of a chloride leachability study performed on Iron-Rich 101. The primary objective of this study was to determine the dissolved chloride concentration in the drainage system on a monthly and annual basis by coupling the results from the pore flush study with the Hydrologic Evaluation of Landfill Performance (HELP) model.

This leachability study was completed in accordance with the Du Pont Environmental Remediation Services *Iron-Rich 101 Chloride Leachability Study Work Plan* dated July 1, 1992. This report presents the laboratory procedures used and the results and conclusions of the study.

2.0 BACKGROUND

Iron-Rich 101, a solid product containing a relatively high concentration of chloride, is proposed for use as a capping material at the Cherry Island Landfill. During rainfall events, it is expected that the chlorides will be washed from the Iron-Rich material and carried into the surface water collection system to be discharged through future National Pollutant Discharge Elimination System (NPDES)-permitted outfalls into the Delaware River and Shellpot Creek.

An extensive study on the kinetics of chloride removal from Iron-Rich 101 was completed by the University of Delaware. This study shows that the desorption of chlorides from Iron-Rich 101 is a first-order nonchemical kinetic related process. This study also indicated that

- The rate of the chloride removal decreased with number of flushes.
- No chemical reactions occurred during the course of the study.

Based on the results of the kinetic study, a leachability evaluation was designed using a flexible wall permeameter and the HELP model to determine the maximum dissolved chloride concentration that can be transported into an NPDES-permitted outfall during individual rainfalls.

3.0 SAMPLE COLLECTION

The Iron-Rich 101 was obtained from the Edge Moor plant. These samples were delivered to the laboratory one day prior to the experiment. The Du Pont Engineering Testing Center (ETC) analyzed the material for total chloride content. Results from this analysis provided the total chloride concentration occurring in the Iron-Rich 101 material prior to being flushed.

4.0 LABORATORY PROCEDURE

4.1 PORE FLUSH STUDY

In the laboratory, the leachability study was performed on the following two types of samples:

- "as is"
- "as is/dry" samples

The "as is" sample was retrieved from the sample provided by the Edge Moor plant without further treatments. The "as is/dry" sample was prepared by drying the "as is" sample at 110°C overnight after flushing the sample with 10 flush volumes or void volumes. This was performed to simulate the wet/dry seasonal changes and evaluate the effect of drying on the removal of chloride from the Iron-Rich 101.

The sample was tightly packed into a flexible-walled permeameter. A catalogue description of this permeameter and the control panel is included in Appendix A. The permeameter is designed so that constant pressure can be applied to the top, bottom, and sides of a sample. Maintaining an equally higher pressure along the bottom and sides and a lower pressure on the top, the water is forced to flow from the bottom to the top of the permeameter. To provide a constant head drop across the soil sample, the difference between the top and bottom pressures was kept constant throughout the study.

Similar infiltration conditions for the soil samples were established by maintaining a similar rate of water flow into and out of the specimen. As expressed by Darcy's Law, flow rate is a function of cross-sectional area, pressure head, and apparent permeability of the soil. For this study, the apparent permeability of the sample changes with degree of compaction and percent moisture; therefore, the hydraulic head applied to the samples was adjusted accordingly to compensate for these differences. Table 1 presents the hydraulic pressure applied to each sample, the resulting flow rate, and the permeability of the samples.

The water leaving the permeameter was drawn into a collector. The collector was replaced every flush until a total of 10 flush volumes or void volumes were collected. For this study, the flush volume of Iron-Rich 101 was approximated by the following equation:

$$V_v = (A)\,(H)\,(n)$$

where
V_v = volume of the voids milliliter (ml)
A = cross-sectional area of the soil sample (square inches)
H = sample height (inches)
n = porosity of Iron-Rich 101

The total void volume is the amount of water needed to saturate the soil sample. The total void volume of Iron-Rich 101 used in this study was calculated to be 15 ml. This is determined using a porosity of 20 percent (based on historic data), a sample height of 3 inches and a cross-sectional area of 1.54 square inches.

The water samples collected from this study were analyzed for free chloride ion concentration. A combined chloride electrode was used for this analysis. For this study, a total of three standards of 0.1, 0.01, and 1 molar sodium chloride solution was prepared to establish a calibration curve for the chloride analysis. Figure 1 depicts the chloride concentration and its corresponding response value in millivolt.

The residual chloride concentration was determined by sending the soil sample from the pore flush study to the ETC for total chloride analysis.

4.2 HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE MODEL

The HELP model was used to identify the infiltration into the drainage system through the proposed cap design at the Cherry Island Landfill. The proposed cap consists of

- A final grading layer on the waste to provide a stable base for subsequent system components.
- An impermeable layer of a 20-ml geomembrane.
- A 12-inch sand layer with a hydraulic conductivity of 1×10^{-3} centimeters per second.
- A final cover with 18 inches of soil to provide rooting depth and moisture for plant growth and 6 inches of topsoil to support vegetative growth.

See Figure 2 for the cross section of the proposed cap design, assumptions, and inputs as simulated by the HELP model.

5.0 RESULTS AND DISCUSSIONS

Table 2 presents the free chloride detected in the flush water from each of the flushes. Figure 3 is the plot of chloride concentration verses the number of flushes.

The results indicate that a majority of the chloride ions were removed from the "as is" sample during the first three flushes. The chloride concentration decreases with the number of flushes and reaches an asymptotic state after eight flushes. A similar phenomenon was observed for the "as is/dry" sample, but lower chloride concentrations were detected and the maximum chloride concentration was not reached until four flushes afterward. This is most likely due to a local equilibrium between the solids and solution having to be established prior to removal of chloride.

Table 3 demonstrates the mass balance between the initial total chloride present in Iron-Rich 101 and the total amount of chloride removed from the pore flush study. The results indicate that 72 percent of the chloride was removed during the first three flushes and a total of 91 percent chloride was removed after 10 flushes from the "as is" sample. Drying of the flushed sample drops the rate of chloride removal; however, this is expected because time is required for the chloride ions to partition from the solids into the solution. It is believed that drying the flushed sample does not inhibit the removal of chloride from the Iron-Rich 101.

Table 4 shows the monthly drainage collected from the drainage system computed from the HELP model and the corresponding pore volumes for a 1.4-square-inch-diameter soil sample. Data shows that a total of 110 ml or an equivalent of seven flushes at 15 ml per flush will be infiltrated through the capping material after one year. It is estimated that a majority (greater than 70 percent) of the chloride can be removed three to four months after the cap is installed.

6.0 CONCLUSION

The following conclusions were drawn based on the results from this study:

- Approximately 72 percent of the chloride was removed from the "as is" sample the first three flushes. A total of 91 percent of the chloride was removed from the "as is" sample after 10 flushes.

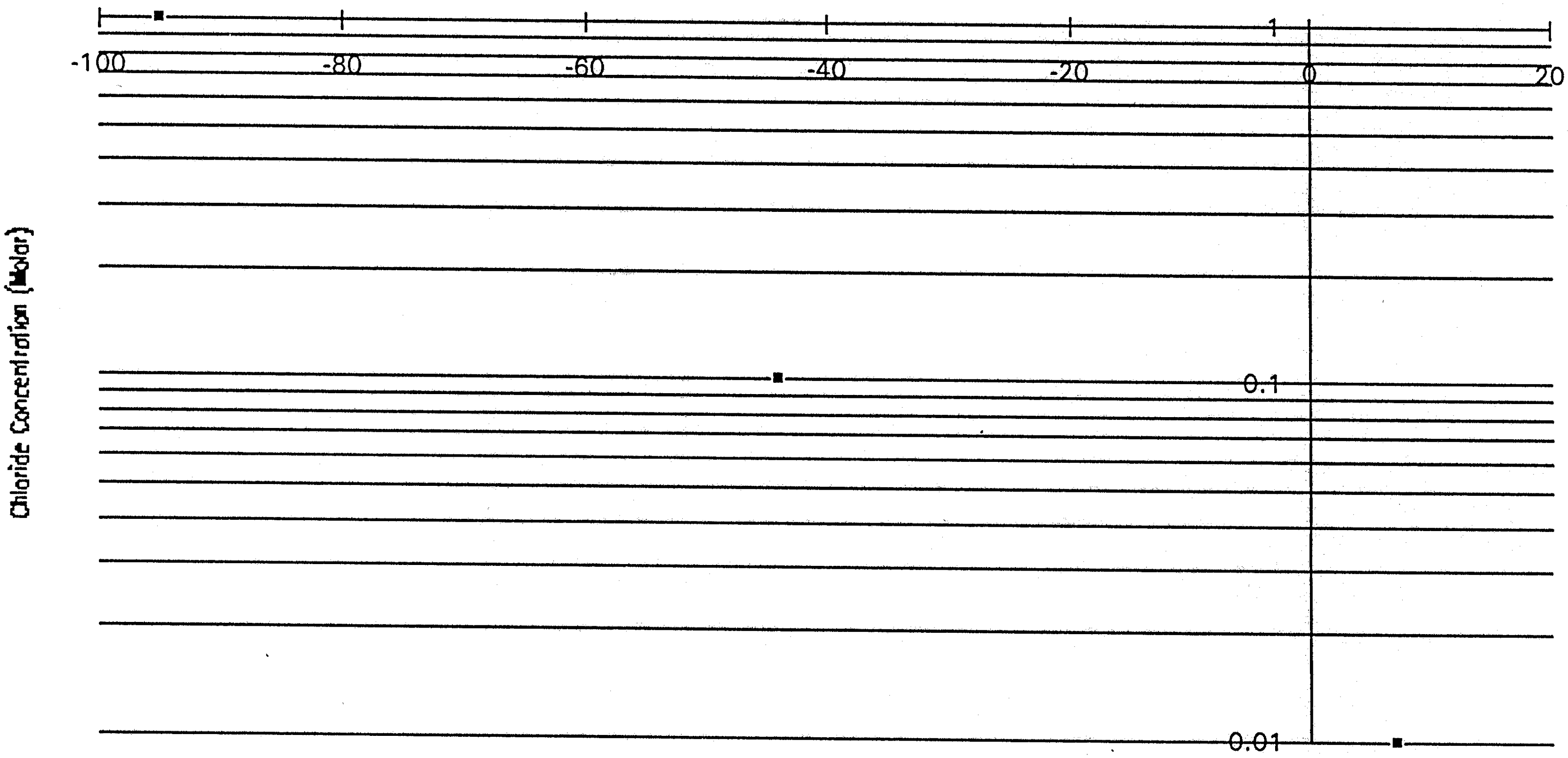
- Drying the flushed sample drops the rate of chloride removal, but this is expected since time is required for the chloride ions to partition from the solids into the solution. It is believed drying the flushed sample does not inhibit the removal of chloride from the Iron-Rich 101.

- The HELP model results show that an equivalent of seven flushes at 15 ml per flush will be infiltrated through the capping material after one year. It is estimated that a majority (more than 70 percent) of the chloride can be removed three to four months after cap installation.

FIGURES

Figure 1

CALIBRATION CURVE FOR FREE CHLORIDE ANALYSIS

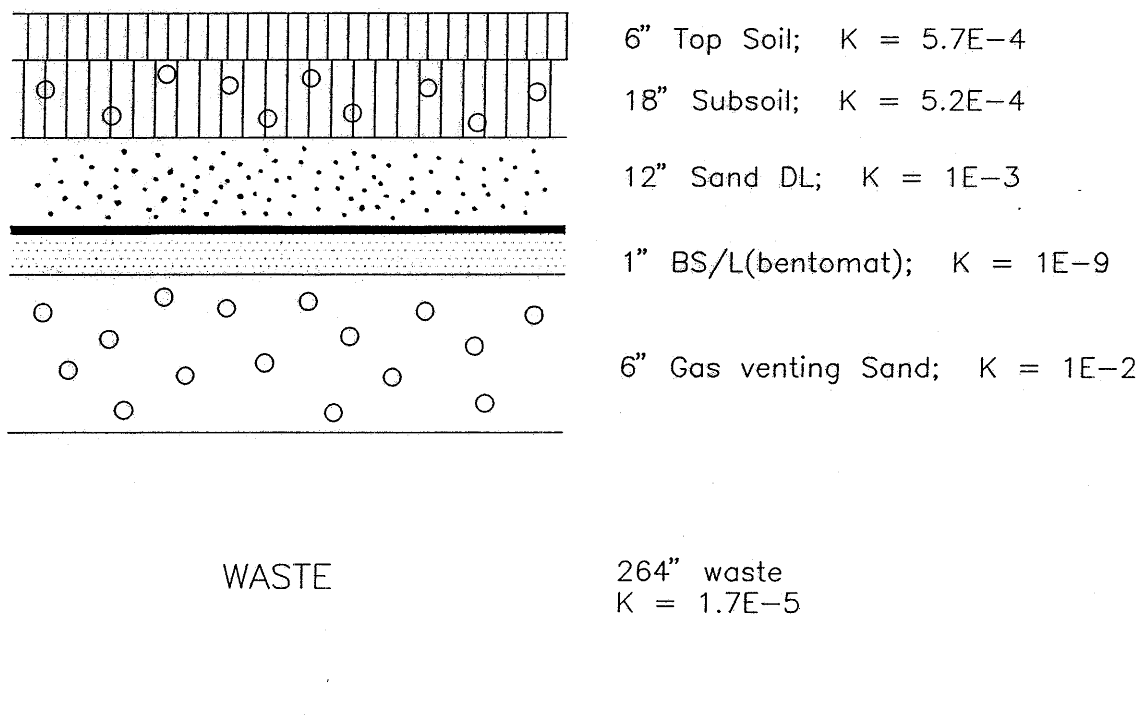


Respose Value (mV)

Figure 2
Assumptions, Inputs, and Cross Section for HELP Model

ASSUMPTIONS & INPUTS

- Wilmington, DE
- 20 yrs. of precipitation data
- Max. leaf index = 2
- E.P. zone depth = 21 in
- SCS #: 72
- Fair grass
- Area = 470,448 ft^2
- Slope(top = 4%, bottom = 2%)
- Drainage distance = 100 ft
- Leakage fraction = 0.0002

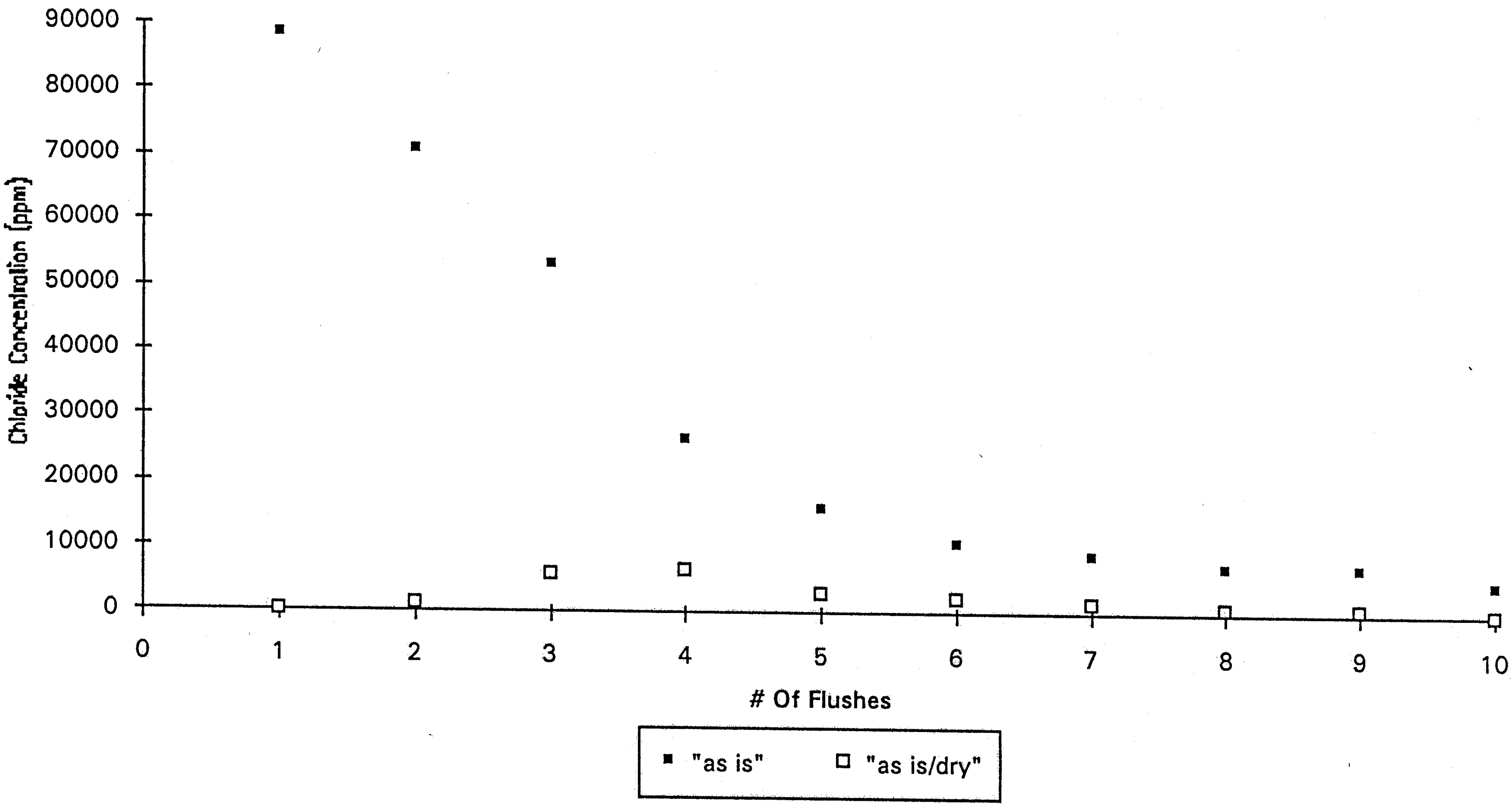


<u>Legend</u>

K	Hydraulic Conductivity (cm/sec)
DL	Drainage Layer
BS	Barrier Soil
BS/L	Barrier Soil with Liner

Figure 3

CHLORIDE CONCENTRATION VS NUMBER OF FLUSHES



TABLES

Table 1

APPLIED PRESSURE HEAD, RESULTING FLOW RATE, AND SAMPLE HYDRAULIC CONDUCTIVITY

	Run No.1 ("as is")	Run No.2 ("as is/dry")
Pressure Head (psi)	2	1
Flow Rate (Q) (ml/sec)	0.011	0.027
Hydraulic Conductivity (K) (cm/sec)	5.90E-05	1.00E-05

Notes:
1 psi = 2.5 ft. of water.
Q is calculated by Darcy's Law .

Table 2

FREE CHLORIDE DETECTED IN FLUSH WATER

Flush No.	Accum. Pore Volume (ml)	Run No.1 ("as is") Chloride Concentration (ppm)	Run No.2 ("as is/dry") Chloride Concentration (ppm)
1	15	88,750.00	11.72
2	30	71,000.00	1,171.50
3	45	53,250.00	5,857.50
4	60	26,625.00	6,443.25
5	75	15,975.00	2,928.75
6	90	10,650.00	2,108.70
7	105	8,875.00	1,405.80
8	120	7,100.00	820.05
9	135	7,100.00	820.05
10	150	4,686.00	117.15

Table 3

A MASS BALANCE BETWEEN INITAL TOTAL
CHLORIDE AND TOTAL CHLORIDE REMOVED FROM PORE FLUSH STUDY

Initial Total Chloride* (mg/kg)	Total Chloride Flushed "as is" (mg/kg)	Total Chloride Flushed "as is/dry" (mg/kg)
59750	54465	6500
% Removal	91	12

* Concentration is reported on dry weight basis.

Table 4

MONTHLY DRAINAGE COLLECTED FROM
THE DRAINAGE SYSTEM AND ITS CORRESPONDING PORE VOLUME

Month	Drainage (in)	Corresponding Pore Volume* (ml)
1	0.3762	8.89
2	0.3575	8.44
3	0.4165	9.84
4	0.4759	11.24
5	0.4702	11.11
6	0.4138	9.77
7	0.3857	9.11
8	0.3440	8.13
9	0.2977	7.03
10	0.2758	6.51
11	0.2400	5.67
12	0.2905	6.86

* Pore volume is calculated based on a sample with a cross sectional area of 9.3 sq. cm.

APPENDIX

Appendix A

CATALOGUE DESCRIPTION OF FLEXIBLE-WALLED PERMEAMETER AND CONTROL PANEL

GEO STORE

FLEXIBLE WALL PERMEAMETER*

The B•K Permeability Cell has been built specifically for performing permeability tests on fine grained soils using flexible walls and back pressure saturation.

The Cell's head and base are machined from an aluminum alloy and anodized for corrosion resistance. Each Cell is supplied complete with stainless steel 2.8" cap and pedestal with porous stones.

Double drain lines at each end of the sample simplify saturation and give greater flexibility in controlling drainage, back-pressure and pore pressure measurement. Continuous teflon tubing goes directly to the end caps from the stainless steel valves, avoiding connections that are potential air traps. As an option, the Cell's valves can be plumbed with stainless steel tubing.

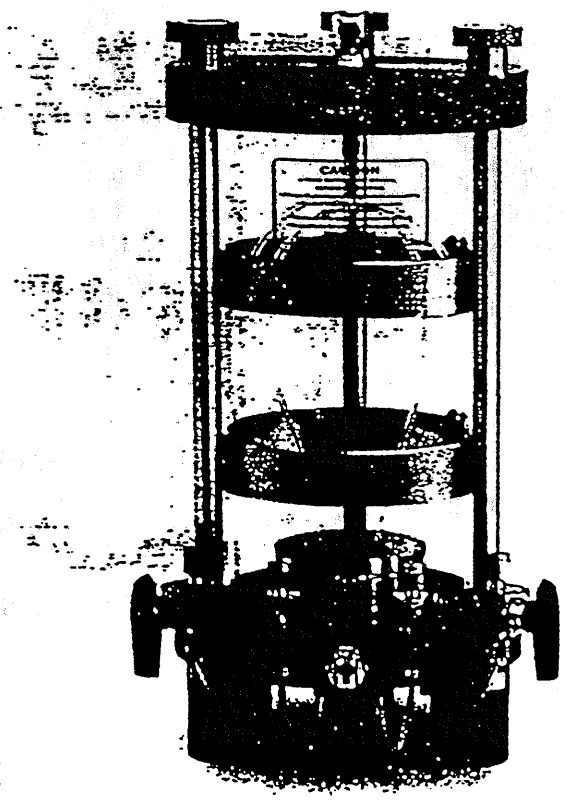
The Cell when used with the Triaxial/Perm. Panel (S-500) provides the complete system for controlling and measuring flow during the permeability tests. In addition, pore pressure transducers and digital readout device allow monitoring of the confining and pore pressures. The Permeameter comes complete as described, and includes 2.8" stainless steel cap and pedestal, 2.8" porous stones, teflon tubing, "O" rings, stainless steel valves and banding.

When using a hazardous or corrosive permeant, the B•K Bladder Accumulator (S-470) is recommended.

Shipping Weight: 16 lbs

MODEL	
S-480	Flexible Wall Permeameter
ACCESSORIES	
S-48010	4" Cap and Pedestal, S.S.
S-48020	Stainless Steel Tubing
RELATED PRODUCTS	
E-400	Digital Transducer Readout
S-470	Bladder Accumulater
S-500	Triaxial/Permeability Panel
E-124	Pore Pressure Transducer 0-150 psi

*Refer to Technical Bulletin TBS-020 for complete specifications.



S-480

ATTACHMENT 3

LIST OF EXHIBITS

Exhibit A	Subsurface Characterization under the IRM Storage Pile
Exhibit B	Peak Stream Flow for Shellpot Creek
Exhibit C	Existing Conditions, Southeast Corner, DuPont Hay Road Sludge Drying Area
Exhibit D	Ian Peggs Paper (2003)
Exhibit E	Transportation Risk Calculation (2007)
Exhibit F	Estimated Volume of Pure Phase Hexachlorobenzene in IRM and DM
Exhibit G	Monitoring Well Location Map
Exhibit H	Iron-Rich 101 Chloride Leachability Study Report (1992)

ATTACHMENT 4

LIST OF ACRONYMS

g/cm^3	grams per cubic centimeter
µg/L	micrograms per liter
ADRE	advection-diffusion-reaction equation
AOC	area of contamination
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/sec	centimeters per second
COPC	constituents of potential concern
DM	dredged material
DNAPL	dense, nonaqueous phase liquid
DNREC	Delaware Department of Natural Resources and Environmental Control
DRBC	Delaware River Basin Commission
ERA	ecological risk assessment
FEMA	Federal Emergency Management Agency
FFS	focused feasibility study
FS	factor-of-safety
GMZ	Groundwater Management Zone
HCB	hexachlorobenzene
HDPE	high density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HI	hazard index
HSCA	Hazardous Substances Cleanup Act
IRM	Iron-Rich material
LADD	lifetime average daily dose
LDRs	Land Disposal Restrictions
mg/L	milligrams per liter
mg/kg	milligrams per kilogram
mm	millimeter
MSL	mean sea level
NAPL	nonaqueous phase liquid
NAVD	North American Vertical Datum
NCP	National Contingency Plan
NGVD	National Geodetic Vertical Datum
OCDF	octachlorodibenzofuran
PCB	polychlorinated biphenyl
PPE	personal protective equipment
ppt	parts per trillion
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RF	reduction factor
RI/FS	remedial investigation/feasibility study
RI/RA	remedial investigation/risk assessment
SIRB	Site Investigation and Restoration Branch
S/S	stabilization/solidification
SVOC	semivolatile organic compound

TAL	target analyte list
TCL	target compound list
TCLP	toxicity characteristic leaching procedure
TEQ	toxicity equivalent
UECA	Uniform Environmental Covenant Act
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
WHO	World Health Organization

ATTACHMENT 5

REFERENCE LIST

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